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Biotechnology in New Zealand

Description and Analysis based on the 1998/99 and 2002 Biotech Surveys and a Review of Secondary Sources

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Abstract

This paper provides a detailed description of the New Zealand biotechnology sector based on a re-analysis of the first comprehensive (1998/99) survey of biotechnology in New Zealand, data from an original (2002) survey conducted by the author and a detailed review of secondary sources. It provides the background for a study of the determinants of innovation reported elsewhere (Marsh, 2004).

A review of alternative data sources on sector size and characteristics is followed by a comparison of New Zealand and international biotech indicators. Data is presented on enterprise type and size and the age distribution of New Zealand biotech enterprises. This is followed by an analysis of innovative output using data on new products, processes and patents. Data is also presented on partnerships and alliances, information sources and other factors affecting innovative performance.

Keywords

biotechnology; innovation, New Zealand, patents; survey data

JEL Classification

L65, L66, O31, O32

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Access to the data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. Standard Statistics' random rounding to base three has been applied to all output. Disclaimer: the results presented in this study are the work of the author not Statistics New Zealand.

Biotechnology in New Zealand

Selected Highlights

Sector Characteristics

- In 1998/99 New Zealand's modern biotech 'sector' consisted of approximately 57 enterprises, employing around 1700 people (the modern biotech 'sector' is defined here as the population of private and public sector enterprises that carry out modern biotech R&D).
- They reported expenditure on biotech of NZ$202 million and income from biotech of NZ$236 million for 1998/99. This compares to enterprise income from all sources of NZ$2.1 billion i.e. biotech provided around 11% of income for the 57 enterprises.
- Data from the 2002 survey indicates that annual growth in expenditure may be as high as 20%.
- Most activity is concentrated in universities, Crown Research Institutes (CRI) and a small number of private sector companies e.g. Genesis, Virionyx, ViaLactia.
- Enterprises in the modern biotech sector are split fairly evenly between the private sector and the public sector.

Research and Development

- Respondents to the 2002 biotech survey indicated that R&D constituted around 10% of total expenditure.
- Expenditure on biotech R&D comprised around 80% of all biotech expenditure.
- Around 60% of all 'biotech staff' were engaged in R&D.
- Respondents spent far more on R&D than the industry average. For example the dairy industry is reported to spend around 1% of turnover on R&D, while R&D expenditure as a proportion of value added of manufactured products was 1.3 percent in 1999/2000.

Development of the NZ Biotech Industry

- Data on the age distribution of biotech process use provides useful information on the development of the biotech industry over time and may also be compared with similar data from overseas.
- Average age in use in New Zealand is longer than in Canada for all but two process categories, possibly because of the lower number of new entrants in New Zealand.
- There are distinct differences between modern and older biotechnology processes. Genomics exhibits a typical age structure for a recent process; 56% have used this process for 5 years or less, 83% have used it for 10 years or less.
- Extraction/purification/separation is typical of a more mature technology; 24% started using this process within the last 5 years (often these are new enterprises). A further 24% have been using this process for at least 20 years.

Biotech Alliances

- Most enterprises (84%) responding to the 2002 biotech survey had at least one alliance involving biotech activity.
- 62% reported at least one New Zealand alliance while 41% reported an overseas alliance.
- Overseas alliances were most common in the tertiary education, and scientific research groups.
- The most commonly reported alliance purposes were product/process development; reported by 82% of respondents who had an alliance and basic research.
- Respondents were asked to rate ‘partnership outcomes to date’; 50% were described as ‘very productive’ and 44% as ‘somewhat productive’. Only 6% were reported to be ‘not very/not at all productive’.

Innovative Output

- One indication of the rate of innovation by biotech respondents is provided by questions such as: “In the last 3 years, how many new or significantly improved products or processes has this business introduced on to the market?”
- Overall, 51% of respondents to the 2002 biotech survey reported implementation of a new product with the innovation rate being lowest for food manufacturers (33%) and highest for non-food manufacturers (79%).
- Process innovation rates were much lower with only 21% reporting implementation of a new process in the last 3 years; this is notably different to the 1998/99 survey when 33% of enterprises reported introduction of new products and the same percentage reported introduction of new processes.
- New Zealand biotech firms do not appear to have a particularly high rate of new product or process development relative to other New Zealand sectors or to other countries.

Patenting

- New Zealand’s rate of modern biotech patent applications over the five years to the end of 2002 was 3.7 per million of population, per year. This is below the average for the G7 (5.3) and for a reference group of small, developed OECD economies (5.5).
- Overall New Zealand ranks eleventh out of 18 with a patenting rate above that found in France and Japan.
- New Zealand’s performance is disappointing compared to other small countries with strong primary industries that it might hope to emulate e.g. Denmark (15.2), Switzerland (10.9), Netherlands (5.5), Australia (4.1).
- Comparison of the three-year periods 1997-99 and 2000-02 reveals an average increase in patenting rates of 51%. New Zealand has increased its performance relative to the OECD and Australia; although the rapid change in patent application rates may, in part reflect an increased propensity to patent in universities and Crown Research Institutes.

International Comparisons

- The OECD has taken the lead in attempting to develop internationally comparable statistics on biotechnology but the variety of definitions and data collection methods make reliable comparisons almost impossible.
- In the OECD's '2003 Scoreboard', New Zealand is reported to put the highest proportional effort into biotech R&D (biotech R&D as a proportion of total R&D). This results both from New Zealand's R&D specialisation in the primary sector and from use of a broad definition of what constitutes biotech R&D.
- However New Zealand's total government expenditure on biotech R&D is the third smallest of the 21 countries listed.
- A more accurate international comparison can be made with Canada, based on data from the Statistics New Zealand biotech survey, since this was closely modelled on surveys carried out by Statistics Canada.
- New Zealand's biotech revenue per million population (NZ$54 million) is lower than Canada's (NZ$94 million), but the difference is fairly small considering Canada's higher per capita income and proximity to the United States.
- New Zealand has a lower mean revenue per biotech firm (NZ$5.3m vs. NZ$8.0m); consistent with the predominance of small firms in the New Zealand economy.
- New Zealand appears to have a significantly higher rate of biotech employment.
- There is some evidence that use of biotech processes in New Zealand is at an earlier stage with 72% being at the R&D stage against 49% in Canada.

1 Introduction

Despite the small size of its economy and of its science base New Zealand has had a significant role in the development of modern biotechnology. Indeed a New Zealand born biophysicist, Dr Maurice Wilkins assisted at the birth of modern biotechnology through the first description of the structure of DNA. Wilkins was later jointly awarded the Nobel Prize for this work together with Crick and Watson.

Much of New Zealand's work builds on national strengths in agricultural and primary industry production and research. But there are also a number of new enterprises at the forefront of research in health and in intellectual property. Recent examples cited by the industry organisation BIOTENZ (1998) include: breeding of transgenic crops; clonal afforestation; genetic manipulation of flower colour; the world's first enteric bacteria-based bio insecticide; a project to map the sheep genome; the world's first sheep genetically engineered for increased wool production; and the world's first recombinant livestock vaccine to combat sheep measles. More recently the report of the biotechnology taskforce noted that:

> New Zealand has significant strengths in large animal biology (in particular being world leading in overall knowledge of the sheep and dairy cow), as well as having world-class research teams in a number of areas of biomedical science and bioengineering. More recently New Zealand has also emerged as world leading in some areas of enabling technology, which is technology that allows both novel and intensive data collection (Biotechnology Taskforce, 2003, p. 23).

Most modern biotechnology activities in New Zealand are concentrated in universities and Crown Research Institutes (CRI) and a small number of private sector companies e.g. Genesis, Virionyx, ViaLactia. The government has been estimated to spend around NZ$127m per year on biotechnology-related research (Ogilvie, 2003), ranging from genomics to processing of natural products including about NZ$18 million on research involving genetic modification (Wright, 2000, p.7). Biotechnology-related research comprises around 19% of total government R&D spending ($677 million in 2002/2003[1]), making New

[1] See Ministry of Research Science and Technology. (2002). *Briefing to the Incoming Minister of Research, Science and Technology.*

Zealand one of three OECD countries with a share above 10% (OECD, 2003). Genesis has invested over NZ$80 million in research since its inception in 1994 while CRIs and companies such as Auckland UniServices have also been successful in generating research revenue from outside the government sector. Nonetheless it must be recognised that New Zealand's total expenditure on biotechnology research is very small by global standards.

Few innovations or processes in *modern* biotechnology have reached the stage of being commercialised. Genesis Research and Development is perhaps one of the closest to achieving income from a new biotechnology product; it initiated additional US phase II clinical trials of its PVAC Psoriasis treatment in June 2002; one of over 300 biotech products now in phase II or phase III trials[2] (Ernst & Young, 1999b, p. 35).

Over the last few years there has been an explosion of interest in biotechnology in New Zealand. Politicians and policy makers have become increasingly interested in the role that biotech might play in the 'new economy'; and aware of the policy initiatives in support of biotech which have been implemented by many of our competitors. The biotech industry has begun to achieve critical mass and has been increasingly effective in lobbying for policy changes that would make New Zealand more supportive of biotech R&D and innovation. At the same time, increasing levels of popular concern over the safety of some modern biotechnologies culminated in the setting up of the Royal Commission on Genetic Modification that spent over $6 million and 14 months listening to all sides of the debate. In October 2001 the government announced its response to the Royal Commission report, including permission for field trials to restart and a two-year ban on commercial release of genetically modified products[3].

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[2] Clinical trials in the United States are conducted in phases. In Phase II trials, the study drug or treatment is given to a group of 100-300 people to see if it is effective and to further evaluate its safety. In Phase III trials, the study drug or treatment is given to large groups of people (1,000-3,000) to confirm its effectiveness, monitor side effects, compare it to commonly used treatments, and collect information that will allow the drug or treatment to be used safely. Source http://clinicaltrials.gov/ct/

[3] This was lifted, amidst much vocal opposition and lobbying, in October 2003.

In early 2002 the Government released its Growth and Innovation Framework (GIF), which aims to return New Zealand to the top half of the OECD in terms of GDP per capita. The GIF identified three potential growth areas that were worthy of special attention and government effort. These were information and communications technology, creative industries and biotechnology. Task forces were established in all three areas to agree priorities and develop action plans to stimulate growth and develop international competitiveness. The Biotechnology Task Force report was published in May 2003 and focuses on "three essential areas":

> a) the need to build critical mass;
>
> b) the introduction of a package of regulatory reform to create a competitive environment for growth; and
>
> c) the establishment of a robust international network through which to stimulate the flow of international investment" (Biotechnology Taskforce, 2003, p. 3).

In the same month, the government published the New Zealand Biotechnology Strategy. The strategy aims to promote growth in biotechnology and draws on the work of the biotechnology taskforce. The strategy document includes the vision statement that:

> New Zealand responsibly develops and applies our world-class biological knowledge, skills, innovation and technologies to benefit the wealth, health and environment of New Zealanders, now and in the future (Ministry of Research Science and Technology, 2003, p. 3).

It goes on to define three goals that support the Government vision for biotechnology:

1. Build understanding about biotechnology and constructive engagement between people in the community and the biotechnology sector.

2. Grow New Zealand's biotechnology sector to enhance economic and community benefits.

3. Manage the development and introduction of new biotechnologies with a regulatory system that provides robust safeguards and allows innovation.

2 Data Sources and Sector Size

Research into the potential impact of modern biotechnology on New Zealand dates back to a 1983 discussion paper published by the Department of Scientific and Industrial Research (DSIR). The authors aimed to assess the significance for New Zealand industry of new developments in biotechnology and also made suggestions “on aspects of research and development which require emphasis if the perceived industrial opportunities are to be realised” (Hunt et al., 1983). This was followed in 1988 by a Department of Trade and Industry (DTI) study that aimed “to identify the impediments affecting the growth and development of biotechnology in New Zealand and to recommend any action the Government and/or department could take to overcome these impediments” (this has many parallels with the task assigned to the Biotechnology Task Force in 2003). DSIR and DTI did not attempt to quantify biotech activity in New Zealand but did identify 40-50 separate organisations working in the biotech sector.

Kennedy and Davis (1994) assessed the impact of biotechnology on New Zealand industry over the period 1984-94 identifying around 50[4] separate organisations that were making direct use of biotechnology. They did not attempt an “all inclusive review of New Zealand Biotechnology because of the difficulties with the definition of the term biotechnology, and the difficulty in obtaining commercial and confidential information” (Kennedy & Davies, 1994, p. 2).

2.1 Estimates by Tradenz

An early attempt to put a monetary value on New Zealand biotech activity was conducted by Tradenz, based on a series of interviews with representatives from “companies, universities, research and development organisations and professional advisors” (Tradenz, 1994, p. 44). The authors classified the biotech industry into three groups using a broad definition of biotechnology and made estimates of turnover and foreign exchange revenue in each group, see Table 1.

[4] The precise number varies depending on definition of a separate organisation, and approach taken to subsequent mergers and other organisational changes.

Table 1 Tradenz Estimates of Biotech Turnover and Foreign Exchange Earnings in 1994

Group	Description	Members	Turnover $ million	Forex $ million
1	Companies and organisations of a research and development nature which are primarily concerned with the creation of intellectual property in the medical and veterinary field, and to a limited extent its commercialisation	Universities, Crown research institutes Technology development companies	100	10
2	Companies processing and marketing biologically active products - mainly meat, dairy and marine	Processing and marketing Companies (includes nutraceuticals)	150	120
3	Companies manufacturing and marketing generic pharmaceuticals	Pharmaceutical Companies	80	7
All Groups			330	137

Source: Tradenz (1994, p. 44)

Tradenz concluded that total turnover was around NZ$330 million with foreign exchange receipts of around NZ$137 million (around 0.7% of total merchandise exports). Industry estimates of growth rates for different categories of firm ranged from 16 to 25% per annum. These figures exclude traditional areas such as dairy and other food production e.g. New Zealand Dairy Exports of NZ$4.6 billion in 1998/9. By including biotechnology in traditional food applications (Cheese, yoghurt, beer) and natural health products including deer velvet, BIOTENZ (1998) predicted that the industry could have a turnover of NZ$7-11 billion in 2010.

2.2 The 1998/99 Biotechnology Survey

The most comprehensive attempt to quantify biotech activity in New Zealand was commissioned by the Ministry of Research Science and Technology (MORST) in 1999. The main purpose was to "produce statistics concerning the present position of this industry in New Zealand" in order to "take stock of the current situation for planning purposes"(Statistics New Zealand, 2000, p. 1). The survey was intended to focus only on modern biotechnology since it was thought that "the contribution to future economic development resulting from modern biotechnology is likely to be much greater than the potential contribution by its traditional counterpart". The objectives[5] of the survey were:

i. To understand the present status, the structure and the future progression of the biotechnology industry in New Zealand
ii. To assess the present status of strategic alliances, the links with the public / private research system and the potential for cluster development for the biotechnology industry
iii. To provide a baseline on the utilisation of resources including the knowledge in the biotechnology industry against which progress could be compared at a future date
iv. To identify the enabling factors and constraints facing the biotechnology industry in New Zealand

The 1998/99 survey of modern biotechnology activity in New Zealand was conducted by Statistics New Zealand in 2000 with the results being published in April 2001[6]. Questionnaires were sent out to 426 enterprises that had been identified as possible users of modern biotechnology processes. The survey achieved a 98% response rate with 180 enterprises being identified as users of at least one biotechnology process. The high response rate and wide ranging processes used to identify possible users of modern biotechnology suggest that the survey is likely to have captured almost all significant users of *modern* biotech in New Zealand over the survey period (1998/99).

The survey also included enterprises that use *traditional* biotech processes (TBU). Estimates on the size of the traditional biotech 'sector' cannot be regarded as being complete since a significant numbers of other users of such processes were not included in the survey, or reported that they did not use modern biotech and so

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[5] Source: Ministry of Research, Science and Technology (2000) *Draft Objectives for the Biotechnology Survey*.

[6] Statistics New Zealand. (2001). *Modern Biotechnology Activity in New Zealand*. Wellington.

did not fill in the questionnaire. For example 33 ‘local authority’ enterprises reported use of biotech processes – primarily for treatment of sewage and wastewater but around 20 reported no involvement.

Marsh (2001a) extensively re-analysed the SNZ dataset[7]. He reported that around 80 biotech respondents conducted R&D; 57 of these conducted R&D into modern processes. Marsh also applied the Statistics Canada definition of a biotech enterprise to the SNZ data set ((Marsh, 2001a, p. 26). Based on this definition, the New Zealand biotech sector consisted in 1998/99 of 39 biotech enterprises with income from biotech of $205 million.

2.3 The 2002 Biotechnology Survey

In 2002 Marsh (2002) designed and implemented a survey of all enterprises in New Zealand that used modern biotech processes and/or all enterprises that conducted R&D using biotech processes (modern or traditional). Data from this survey are used in this paper to describe biotechnology in New Zealand and were also used to test a series of key hypotheses about the determinants of innovation.

The 2002 survey was conducted by the author, in order to address research questions not covered in the 1998/99 biotech survey. The questionnaire was designed and drafted based on an iterative process involving consideration of:

i. the data that should ideally be used to test the hypotheses;
ii. the data or indicators that have been used in previous studies;
iii. the outcome of those studies; and
iv. the data or indicators that New Zealand respondents were likely to be willing and able to provide.

International experience in the practice of surveys of innovation and biotechnology was reviewed; particularly Community Innovation Surveys conducted in the EU e.g. (Muzart, 1998) etc, OECD innovation surveys (OECD,

[7] Some of his results presented here may appear to conflict with those published by Statistics New Zealand. This is mainly explained by different treatment of multiple responses from single enterprises.

2002), OECD studies of biotechnology e.g. (van Beuzekom, 2001) and Statistics Canada biotechnology surveys e.g. (McNiven, 2001a; Pattinson, Van Beuzekom, & Wyckoff, 2001). An extended email discussion was also held with staff at Statistics Canada; the first national statistical organisation to implement a comprehensive biotechnology survey.

Survey design took account of New Zealand experience with studies of innovation and biotechnology; most notably lessons learned in the conduct and analysis of the 1998/99 survey of modern biotechnology; see (Marsh, 2001b), R&D expenditure surveys e.g. (Ministry of Research Science and Technology, 2002) and business practices surveys; see (Statistics New Zealand, 2002). Survey design was also discussed with government (MoRST and SNZ) and representatives of the biotechnology industry. A detailed research proposal was written up and circulated for comment. Ethical approval was secured from the Waikato Management School ethics committee.

The study population was defined as 'all enterprises using modern biotech processes and/or all enterprises conducting R&D using biotech processes (modern or traditional)'. Inclusion of enterprises that conduct R&D using modern *and* traditional processes allowed investigation into the differences between these organisations. Enterprises that use traditional processes only and do *not* carry out R&D were excluded for both practical and theoretical reasons. In practice, they are not well suited to a study of innovation as they tend to exhibit low innovation rates and an unwillingness to participate in voluntary innovation surveys. From a theoretical perspective these enterprises are of less interest since the hypotheses tested focus on factors affecting innovative output and innovation rate – rather than why enterprises are, or are not innovative. It should also be noted that these enterprises would not normally be regarded as being part of the biotech 'sector'.

Enterprises contacted were identified from a database of all biotech enterprises in New Zealand built up over three-year period 1999-2002. Entries in the data base are based on data from a variety of sources including:

i. the NZBA web directory;
ii. firms and organisations attending NZBA conferences;
iii. the BIOTENZ website;
iv. A'Courts and other commercial directories;
v. internet searches;
vi. print media articles (internet searches based on key words such as biotech, gene etc);
vii. the website of the Royal Commission on Genetic Modification;
viii. the FRST website; and
ix. published sources e.g. Kennedy & Davies (1994) and Packer, Robertson, & Wansbrough (1998).

A total of 146 questionnaires were sent out in April 2002. Responses were received from 93 enterprises indicating a 'crude' response rate of 64%. The sample frame was adjusted to 138 enterprise units by subtracting enterprises that reported that they were not involved in biotech. Sixty one usable responses were received indicating a 'usable' response rate of 44%.

2.4 Overview of Sector Size Estimates

Recent attempts to quantify New Zealand biotech activity are summarised in Table 2. It may be seen that different interpretations of the terms biotechnology and biotechnology sector continue to hinder attempts to measure biotech activity in a way that is comparable over time and across nations.

Ernst and Young publish annual reports on the state of the biotech industry in various countries (Ernst & Young, 1999a, 1999b); in their survey of the Australian industry they identified 120 core biotechnology companies. They excluded not-for-profit enterprises and traditional biotechnology operations and defined 'core biotechnology' companies as "those whose business is entirely or substantially biotechnology related and that have a significant commitment to technological innovation". Based on this definition there were around 30 core biotech enterprises in New Zealand in 1998/99.

Estimates of the size of the New Zealand biotech sector range from 30 core biotech companies with annual income of the order of $200 million, to the Biotechnology Taskforce (350 organisations in the ‘biotech community’) to BIOTENZ income estimates of several billion dollars (including traditional food applications such as cheese, yoghurt and beer).

These alternative estimates serve different purposes and are not mutually exclusive. Authors aiming to take a comprehensive approach that promotes all New Zealand organisations that use biotech tend to include both traditional and modern applications. On the other hand international statistics and the economic literature since the mid 1980s has generally concentrated on modern biotechnology and the biotech sector is often taken internationally to refer to the population of ‘core’ private sector enterprises that conduct R&D into *modern* biotechnology.

Table 2 Size of the New Zealand Biotech Sector

Source	Year	No. of Enter-prises	No. of Empl-oyees	Biotech Income $ million	Remarks
BIOTENZ Capability Survey (Cooper, 2003)	2003	258 42 *core*	4000		Comprehensive survey of the biotech community including core biotech firms, natural products and suppliers.
Biotechnology Taskforce (2003)	2003	350 40 *core*	3900		350 organisations in the “biotech community” includes natural product manufacturers, importers, lawyers, consultants, equipment suppliers, government agencies etc
Hopper and Thorburn (2003)	2002	60 *core* 70-80 *other*	1200		60 “dedicated, core biotech firms …70-80 involved in biotech in a more minor way”
Statistics New Zealand (2001)	1998 /99	180	2727[8]	475	Includes most enterprises that use modern biotech and some that use traditional biotech processes
Marsh (2001a)	1998 /99	57	1667[9]	236	Includes only enterprises that use modern processes and conduct R&D
Marsh (2001a)	1998 /99	39	1708[10]	205	Based on Statistics Canada definition of a biotech enterprise[11]
Marsh (2001a)	1998 /99	27			No. of Dedicated Biotech Enterprises (DBF)[12]
Kennedy (1994)	1993	50[13]			Broad definition of biotech
Tradenz (1994)	1994			330 *turnover*	Broad definition of biotech

Source: various sources collated by the author

Marsh (2001a) divided users of biotech processes into four categories (see Figure 1) based on whether they used modern or traditional processes and whether they were creators (engaged in R&D) or simply users of biotechnology processes. The

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[8] Head count of employees associated with biotechnology

[9] Full-time equivalents (year to 30 June ’99)

[10] Head count

[11] conduct R&D, have a minimum of five biotech employees and biotech expenditure of at least NZ$150,000

[12] DBFs defined as enterprises that received 100% of their income from biotech. A further nine received 75-100% of their income from biotech.

[13] The precise number varies depending on definition of a separate organisation, and approach taken to subsequent mergers and other organisational changes.

term Modern Biotech Enterprise (MBE) is used to describe respondents that are engaged in R&D into at least one modern biotech process.

Figure 1 Classification of Biotech Respondents

	Modern ! ! ! ! ! Traditional	
Creators ↓ ↓	Modern Biotech Enterprises (MBEs)	Traditional Biotech Enterprises (TBEs)
↓ ↓ **Users**	Modern Biotech Users (MBUs)	Traditional Biotech Users (TBUs)

Source: Marsh (2003)

Based on this definition, New Zealand's modern biotech 'sector' consisted in 1998/99 of approximately 57 enterprises (15 primary product and manufacturing firms, 24 research organisations and 6 universities) employing around 1700 people. Enterprises were split fairly evenly between the private sector (30) and the public sector (27). They reported expenditure on biotech of NZ$202 million and income from biotech of NZ$236 million. This compares to enterprise income from all sources of NZ$2.1 billion, i.e. biotech provided around 11% of income for the 57 enterprises. Twelve enterprises reported that they received all of their income from biotech and so might be referred to as dedicated biotech firms. A selection of key indicators of biotech activity based on analysis in Marsh (2001a) is provided as Table 3.

Table 3 Key Indicators of Biotech Activity in New Zealand 1998/99

	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Biotech Respondents
No. of Respondents and Processes					
No. of Respondents	57	24	36	63	**180**
No. in Private Sector	30	21	21	30	**102**
Biotech Processes per enterprise	19	3	8	4	**9**
No. Involved in DNA Based Processes	42	0	9	0	**51**
Innovation Indicators					
No. New Products last 3 yrs	114	18	27	18	**180**
No. New Processes last 3 yrs	105	21	45	9	**177**
New Products & Processes per Enterprise	3.8	1.8	2.0	0.4	**2.0**
No. Processes New to the World last 3 yrs	30	6	3	0	**39**
No. New Products Planned Next 3 years	207	24	42	21	**298**
No. New Processes Planned Next 3 years	219	12	24	30	**288**
New Products & Processes per Enterprise	7.5	1.5	1.8	0.8	**3.3**
No. of Patents Applications Last 5 Yrs	147	6	3	0	**156**
Patents Applications per Enterprise	2.6	0.3	0.1	0	**0.9**
Biotech Income and Exports					
Total Income ($ million)	2,124	1,008	1,647	2,475	**7,254**
Biotech Income ($ million)	236	68	112	59	**475**
Biotech as % of Total Income	11%	7%	7%	2%	**7%**
Biotech Income per Enterprise ($ million)	4.1	2.8	3.1	0.9	**2.6**
Biotech Exports ($ million)	60	*c*[1]	40	*c*	**170**
Biotech Employment					
Full-time Equivalents (yr to 30 June '99)	1,667	218	944	155	**2,984**
PhDs	667	*c*	*c*	*c*	**703**
Graduates	1,512				**1,824**
Graduates per Enterprise	27				**10**
Biotech Alliances					
% Reporting Biotech Alliances	90%	50%	42%	24%	**53%**
% Reporting Alliance with CRI	68%	25%	17%	14%	**32%**
% Reporting Alliance with Business	47%	13%	17%	10%	**22%**

Source: Marsh (2001a).

Note: *c* indicates cell 'confidentialised' to give effect to the confidentiality provisions of the Statistics Act 1975.

A further 36 enterprises *used* modern biotech processes (but were not engaged in R&D) and employed around 950 people in 'biotech based activities', which provided income of NZ$112 million. Twenty four enterprises, employing around 220 people conducted R&D using *traditional* biotech processes but were not involved in *modern* biotechnology.

2.5 International Comparisons

The OECD has taken the lead in attempting to develop internationally comparable statistics on biotechnology. It held the first ad hoc meeting on Biotechnology Statistics in March 2000 and decided to address the lack of biotechnology statistics in OECD member and observer countries by preparing a compendium of biotechnology statistics (van Beuzekom, 2001). The compendium provides an invaluable source of information on biotech in the OECD, although the variety of definitions and data collection methods make the production of reliable comparisons pretty well impossible. Selected data from Van Beuzekom and a recent update by Devlin (2003) are summarised in Table 4.

Table 4 Biotechnology in Numbers

	Data Year	Total Number of Companies Involved in Biotech	Number of 'Core'[1] Biotech Companies	Total Number of Biotech Employees	'Core' Biotech Companies per million inhabitants, 2000[7]
Australia	'99		120	3801	
Belgium	'97	52		4471	5.3
Canada	'99		358	7695	12.2
Denmark	'98		74	34116	9.6
Europe	'99		1351	53511	
Finland	'99		110	8200	10.4
France	'99		380	11000[2]	5.8
Germany	'99	709	279	228845[3]	5.9
Ireland	'99	140	50		11.2
Israel	'99		135	3800	
Italy	'99		45		1.1
Japan	'99	1000	394	29358[4]	
Netherlands	'99	300	55		5.0
Norway	'00		44	10154	8.3
New Zealand[5]	'00	250-350	40	2727	10.4
Spain	'99	200	22	90000	0.8
Sweden	'99		144	2998	26.0
Switzerland	'99	233	117	7000	12.6
UK	'99		275	13780[6]	7.6
USA	'99		1273	162000	

Source: van Beuzekom (2001, p. 42) and Devlin (2003, p. 11)
Notes: 1. 'Core' biotech firms have their main activities in biotechnology although they can be active in other fields. 2. Only covers 255 companies. 3. Covers all 709 companies. 4. Only covers 210 companies. 5. Data inserted based on Table 2. 6. Based on 221 companies and 1997 data. 7. Data from Devlin (2003, p. 11)

The 2001 edition of OECD's STI Scoreboard (2001) included data on public funding of biotechnology R&D and patents, for the first time, see Table 5. Data for New Zealand have been inserted based on Rolleston (1999, p. 46) who reported that the government spent an estimated NZ$100m a year[14] on biotechnology-related research ranging from genomics to processing of natural products and Wright, (2000, p. 7) who reported that around NZ$18 million is spent on research involving genetic modification (Wright, 2000, p.7).

Table 5 Government Funded Biotechnology R&D 1997& 2000

	1997 Biotechnology R&D, 1997 $ million PPP	1997 GBAORD[1] $ million PPP	1997 Biotech R&D as % of GBAORD	2000[2] Biotech R&D as % of GBAORD
Australia ('98)	196.3	2533	7.8	8.0
Austria	16.8	1147	1.5	
Belgium	181.7	1314	13.8	
Canada	261.4	2581	10.1	10.6
Czech Republic ('99)	7.8	749	1.0	
Denmark	45.2	946	4.8	10.4
Finland	94.5	1165	8.1	9.0
France	560.0	12683	4.4	
Germany	1048.2	15596	6.7	3.1
Greece	6.5	431	1.5	8.3
Iceland	0.9	69	1.3	
Ireland	15.0	230	6.5	0.6
Italy	32.1	7330	0.4	0.7
Netherlands	78.0	3070	2.5	
New Zealand[3]	12.3–68.0	400	3-17	14.6
Norway[4]	26.8-32.2	880	3-3.7	3.7
Portugal	19.2	782	2.5	
Spain	15.5	3203	0.5	3.2
Sweden[5]	65.6	1795	3.7	
Switzerland[5]	16.4	1380	1.2	
United Kingdom	705.1	9056	7.8	2.6

Notes: Sources (OECD, 2001, 2003) and authors estimates.

1. GBAORD; Total Government Budget Appropriations or Outlays for R&D.
2. 2000 or nearest year available, Eurostat National Sources May 2003.
3. Author's estimates based on published data.
4. National estimates.
5. GBAORD has been estimated.

[14] Consistent with estimated spending of $127 million in 2002/3, (Ogilvie, 2003).

Based on Wright's narrower definition, New Zealand is spending around 3% of GBAORD[15] on biotech R&D – giving it a middle ranking amongst the OECD members reported above. Probably a rather wider definition should be adopted suggesting that New Zealand's proportional effort on biotech R&D is comparable with the leaders e.g. Canada, Australia Belgium, UK. This approach was taken by the OECD (2003) which reported that New Zealand put the highest proportional effort into biotech R&D[16]. Not surprisingly, a rather different picture emerges in absolute terms with New Zealand's total biotech GBAORD being the third smallest of the 21 countries listed.

Some more accurate international comparisons can be made based on data from the Statistics New Zealand biotech survey, since this was closely modelled on surveys carried out by Statistics Canada. However there are some important differences; the New Zealand definition of biotech included several additional processes and so was somewhat wider than that used in Canada; the number of biotech firms is also not directly comparable since the Canadian survey excluded firms that had less than five employees and less than C$100,000 R&D expenditure.

An approximate comparison between the two data sets is included as Table 6. It is based on application of the Statistics Canada definition of a biotech enterprise to the New Zealand data set; namely enterprises which conduct R&D, have a

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[15] Government Budget Appropriations or Outlays on R&D

[16] Major differences in biotech R&D as a percentage of GBAORD between 1997 and 2000 (see Table 5) are probably caused by changes in definition. R&D definitions for the 2000 data vary across countries, especially with respect to inclusion or exclusion of biotechnology R&D performed by the higher education sector. The data are based on: government budget appropriations or outlays for R&D (GBAORD) for Australia, Canada, Germany, Greece, Ireland, Italy, Korea, Spain and the United Kingdom; government-financed gross domestic expenditure on R&D (GERD) for Norway; and the sum of R&D performed by the government, higher education and private non-profit sectors for Denmark, Finland and New Zealand (OECD, 2003).

minimum of five employees and biotech expenditure of at least NZ$150,000. Data for Australia are also included although based on a narrower definition.

Table 6 Comparison of Biotech in New Zealand, Canada and Australia

	Canada 1999	Australia 1998/99	NZ 1998/99
Population (1997)	30.3	18.5	3.8
No. of biotech enterprises	358	120	39
Total biotech revenue (NZ$ m)	2850	1077	205
Biotech revenue per million population (NZ$ m)	94	58	54
Revenue per firm (NZ$ m)	8.0	9.0	5.3
Biotech related employees (Headcount)	7695	3801	1708
Biotech related employees per million population	254	205	449
% of products and processes in R&D stage	49%	47%	72%

Sources: NZ - Marsh (2003), Canada - McNiven (2001a), Australia - Ernst & Young (1999a).

New Zealand’s biotech revenue per million population (NZ$54 million) is rather lower than Canada's (NZ$94 million), but the difference is fairly small considering Canada’s higher per capita income and proximity to the United States. New Zealand has a rather lower mean revenue per biotech firm (NZ$5.3m vs. NZ$8.0m); consistent with the predominance of small firms in the New Zealand economy. New Zealand appears to have a significantly higher rate of biotech employment. There is some evidence that use of biotech processes in New Zealand is at an earlier stage with 72% being at the R&D stage against 49% in Canada.

3 Enterprise Types in the NZ Biotech Sector

3.1 Classification by Industry Group

Users of modern and traditional biotech processes are spread fairly evenly over five main industrial groups: food and non-food manufacturers, scientific research, and local government and health services. The proportion of New Zealand enterprises that make use of biotech is very low; fewer than half of one per cent of enterprises in the above industrial groupings. Most modern biotech R&D is conducted within research organisations, universities and a small number of private companies. Table 7 summarises data from Statistics New Zealand (2001) and Marsh (2001a; 2002) on the number of enterprises involved in biotech, by industrial group.

Biotech respondents were concentrated in a small number of industrial groups; 120 of the SNZ’s 180 respondents falling under 8 ANZSIC categories (at the 5 digit level), see Table 8.

Around 60% of SNZ’s biotech respondents were from the private sector (including manufacturers, research enterprises and laboratories), the remainder being mainly comprised of local and regional authorities, universities, crown research institutes and health providers[17]. The smaller number of enterprises responding to the 2000/01 survey reflects a change in the survey population and a lower response rate – not a fall in the number of enterprises.

Table 7 No. of Enterprises Responding to Biotech Surveys, by Industrial Grouping, 1998/9 and 2002

<table>
<tr><th>Industrial Group</th><th>No. Enterprises Involved in Biotech Activity 1998/99</th><th>No. Modern Biotech Enterprises 1998/99</th><th>No. MBE Respondents 2001/02</th><th>No. All Enterprises in each Industrial Group 1998/99</th></tr>
<tr><td>Primary Products</td><td>6</td><td>3</td><td>5</td><td>8,122</td></tr>
<tr><td>Food Manufacturing</td><td>33</td><td>3</td><td>4</td><td>1,268</td></tr>
<tr><td>Non-Food Manufacturing</td><td>24</td><td>9</td><td>8</td><td>591</td></tr>
<tr><td>Scientific Research</td><td>36</td><td>24</td><td>10</td><td>5,404</td></tr>
<tr><td>Local Government Administration</td><td>33</td><td>6</td><td>Not sampled</td><td>201</td></tr>
<tr><td>Tertiary Education</td><td>9</td><td>6</td><td>6</td><td>76</td></tr>
<tr><td>Health Services</td><td>24</td><td rowspan="2">9</td><td rowspan="2">1</td><td>3,536</td></tr>
<tr><td>Other</td><td>12</td><td>25,036</td></tr>
<tr><td>Total</td><td>180</td><td>57</td><td>34</td><td>44,234</td></tr>
</table>

Note: Other includes water supply, sewerage and drainage services, veterinary services, parks and gardens.
Sources: Statistics New Zealand (2001) and Marsh (2001a; 2002).

[17] Formerly known as Crown Health Enterprises

Table 8 Number of Biotech Enterprises Responding to Biotech Surveys, by ANZSIC Category

	1998/99	2000/01
Dairy Product Manufacturing	6	0
Wine Manufacturing	9	0
Medicinal and Pharmaceutical Product	15	10
Manufacturing Scientific Research	24	13
Technical Services nec	6	1
Local Government Administration	33	0
Higher Education	12	12
Hospitals (except psychiatric)	15	1
Total No of Respondent in above categories	*120*	*37*
Other ANZSIC Categories	*60*	*24*

Sources: Marsh (2001a; 2002).

3.2 Classification by Product End-Use

Modern biotechnology is used in a number of different economic sectors ranging from food and non-food manufacturing through various primary industries to health, diagnostic and environmental applications, see Table 9.

Table 9 Classification by End-Use Sector

<table>
<tr><th rowspan="2">End-Use Sector</th><th rowspan="2">SNZ 1998/99 All Respondents</th><th rowspan="2">SNZ 1998/99 MBEs</th><th colspan="2">Hopper and Thorburn 2002[18]</th></tr>
<tr><th>NZ</th><th>Australia</th></tr>
<tr><td>Human Health</td><td>30%</td><td>53%</td><td>29%</td><td>40%</td></tr>
<tr><td>Food Processing</td><td>33%</td><td>42%</td><td>10%</td><td>2%</td></tr>
<tr><td>Mining/Energy etc</td><td>4%</td><td>5%</td><td rowspan="2">8%</td><td rowspan="2">11%</td></tr>
<tr><td>Environment</td><td>35%</td><td>37%</td></tr>
<tr><td>Agbiotech</td><td>32%</td><td>63%</td><td rowspan="3">25%</td><td rowspan="3">19%</td></tr>
<tr><td>Forest Products</td><td>8%</td><td>21%</td></tr>
<tr><td>Aquaculture</td><td>13%</td><td>37%</td></tr>
<tr><td>Genomics</td><td>12%</td><td>42%</td><td rowspan="3">13% including diagnostics</td><td rowspan="3">22% including diagnostics</td></tr>
<tr><td>Custom Synthesis</td><td>8%</td><td>21%</td></tr>
<tr><td>Other</td><td>13%</td><td>21%</td></tr>
<tr><td>Multiple Sector</td><td>na</td><td>na</td><td>13%</td><td>4%</td></tr>
</table>

Sources: Marsh (2001a), Hopper & Thorburn (2003).

Modern Biotech Enterprises reported that they were researching and developing products, processes and services for use in the ag-bio and human health sectors,

[18] Data adjusted by removing biotech suppliers.

followed by food processing, genomics/molecular modelling, aquaculture and the environment. Food manufacturers were generally classified as MBEs because of their use of non-DNA based processes e.g. peptide sequencing, immune stimulants, antigens and antibodies etc.

Other biotech categories exhibit a similar pattern while being influenced by the industry group of some respondents; so for example the environment industry sector was reported most frequently by Traditional Biotech Users, reflecting the waste treatment activities of local authorities, while Modern Biotech Users most reported sector was human health – reflecting the activities of health services respondents.

A similar pattern emerges when ‘end use sector’ is tabulated against industry group see Marsh (2001a, p. 34). The main end use sector is in many cases ‘self defined’:

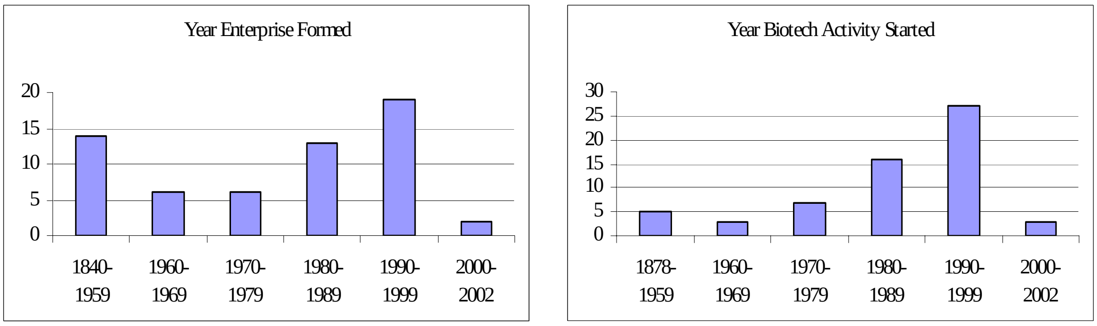
x. Food manufacturers reported food processing as the main end use sector;
xi. Non-food manufacturers were mainly involved in ag-bio, human health and food processing ;
xii. Scientific research organisations were involved in most sectors, ag-bio being the most common;
xiii. Local government was mainly involved in environmental processes (water and waste treatment)
xiv. The university and polytechnic group were involved in all areas; human health being the most common;
xv. Health services organisations were all involved in human health and have some involvement in ag-bio and the environment.

Classification according to end-use may allow better international comparisons but has the disadvantage that many enterprises are involved in multiple sectors. This may explain the lack of correspondence between the end-use sectors reported by Hopper and Thorburn (2003), in which most enterprises were assigned a single end-use sector, and Marsh (2001a) where each enterprise can select several sectors.

3.3 Year of Formation and First Biotech Activity

Enterprises responding to the 2001/02 survey were formed as early as 1840, although 35% had been formed since 1990. Biotech activity was reported to have started as early as 1878 but in most cases had started much more recently; 49% had started since 1990 and 85% since 1970, see Figure 2.

Figure 2 Year of Enterprise Formation and First Biotech Activity



Source: Marsh (2002).

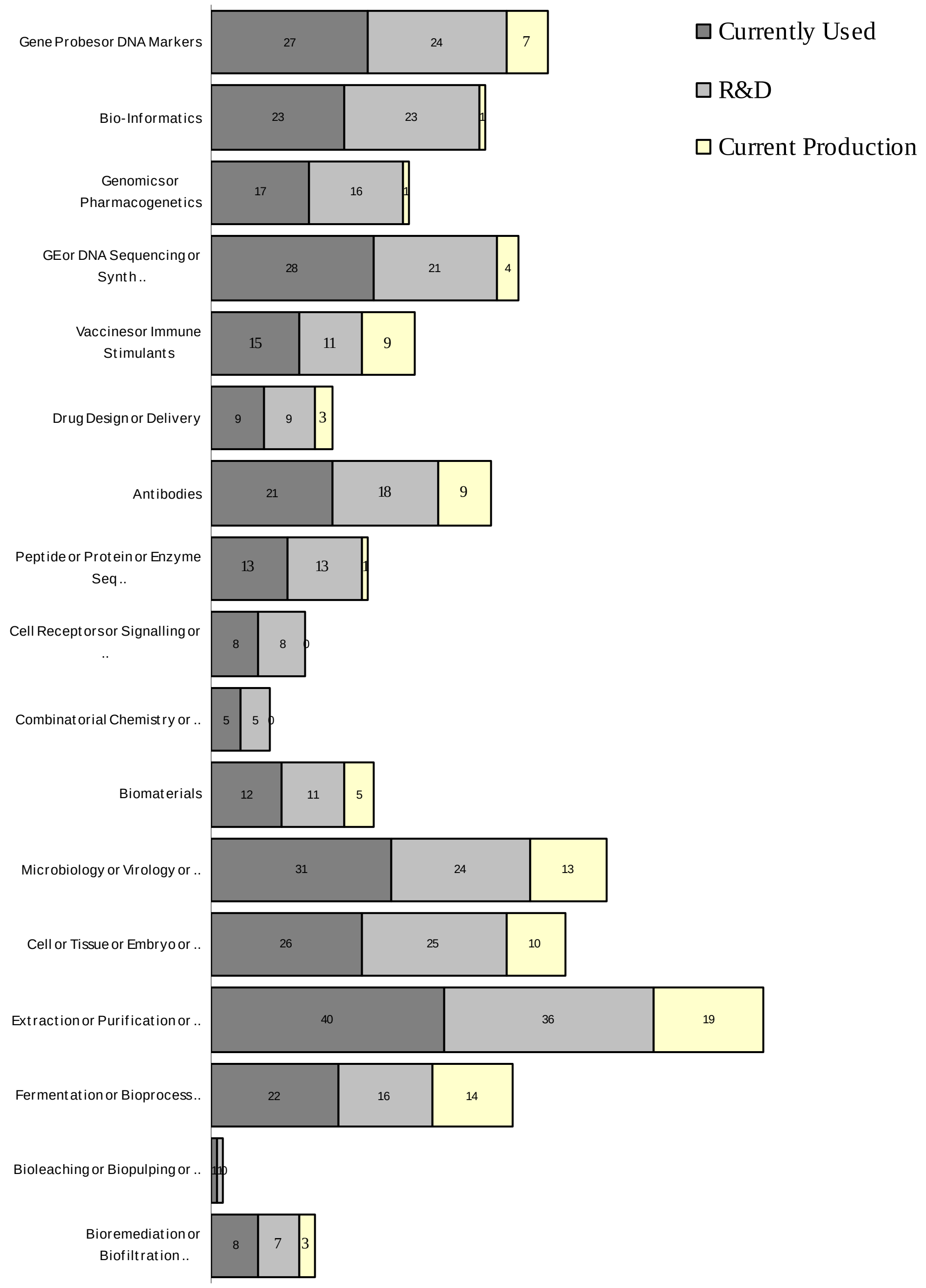
3.4 Biotech Processes Used

Biotech enterprises in New Zealand may also be described by reference to the types of biotech process that they use and whether these processes are used for R&D or for production. Respondents to the 2002 survey were asked to review a list of 17 groups of biotech processes and indicate whether each process/group was currently used for R&D or for current production, see Figure 3[19].

It may be seen that the most commonly used process group was 'extraction, purification etc' followed by 'microbiology or virology etc' and 'gene probes or DNA markers'. The way in which process groups are used varies considerably, so for example bio-informatics and GE or DNA sequencing are used almost exclusively for R&D, while 'fermentation or bioprocessing' is generally used for current production.

[19] This Figure provides data on respondents to the 2002 survey of organisations conducting biotech R&D. For data on *all* biotech users see Marsh (2001a, p. 11).

Figure 3 No. of Respondents Using Biotech Processes in R&D and for Current Production in 2002



Source: Marsh (2002).
Note: 'Currently Used' denotes total number of users including those who use biotech processes for R&D and for 'Current Production'.

Use of modern biotech in New Zealand is at an early stage of development with many enterprises being involved primarily in R&D. Overall 92% of biotech respondents (2002 Survey) used at least one biotech process for R&D or process development, see Table 10.

66% reported use of biotech processes for current production. There is significant variation between the different biotech areas, for example:

i. 90% of enterprises using DNA based processes conducted R&D in this area while only 30% used these processes for current production;

ii. 87% of enterprises using biochemistry based processes conducted R&D in this area while 47% used these processes for current production;

iii. Enterprises using bioprocessing based processes were most likely to use them for current production (63%).

Table 10 Percentage of Enterprises Involved in Different Biotech Areas by Stage in 2002

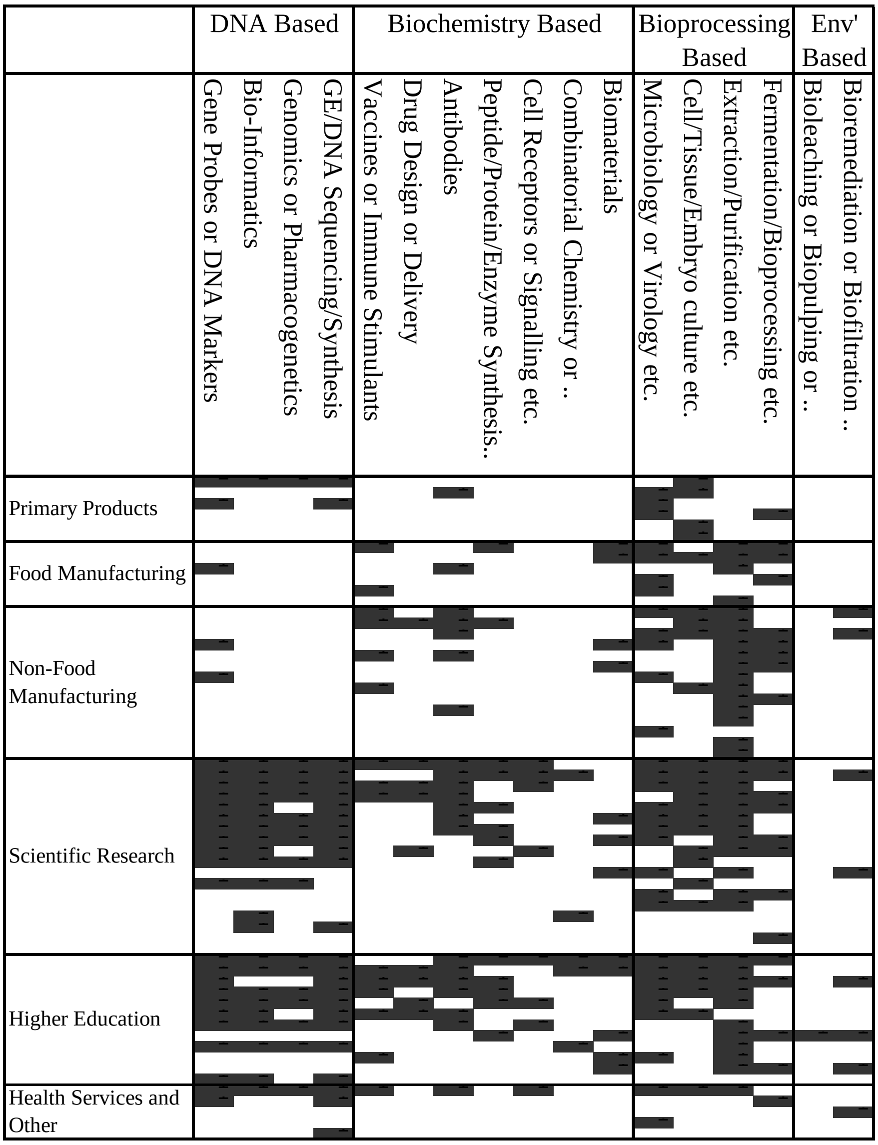
Biotech Area	No. of Enterprises Involved at any stage	% Using Processes in R&D 2000/01	*% Using Processes in R&D 1998/99*	% Using Processes for Current Production 2000/01	*% Using Processes for Current Production 1998/99*
DNA Based Processes	30	90%	*76%*	30%	*24%*
Biochemistry Based	45	87%	*57%*	47%	*43%*
Bioprocessing Based	51	90%	*37%*	63%	*37%*
Environmental Biotech	8	88%	*54%*	38%	*19%*
Enterprises Involved in each Stage	61	92%	*53%*	66%	*45%*

Note: Percentages are expressed as a proportion of the number of enterprises involved in each area e.g. '90% of the 30 enterprises that used DNA based processes used DNA based processes for R&D'. Enterprises may use the same process in more than one stage.
Sources: Marsh (2001a; 2002).

3.4.1 Number of Processes Used

Figure 4 provides a pictorial representation of biotech process use in the different industrial groups. It illustrates the number of processes used in different biotech areas. Each black rectangle indicates use of one process group by one respondent. It can be seen that respondents in scientific research and higher education use the most processes; including most in the DNA, biochemistry and bioprocessing based areas, while manufacturers mainly use bioprocessing based processes. Private sector organisations (primary, food and non-food industrial groups) were involved in fewer process categories – an average of 2.5 to 3.2 per respondent than public sector organisations.

Figure 4 Process Use by Industrial Group



Source: Marsh (2002)

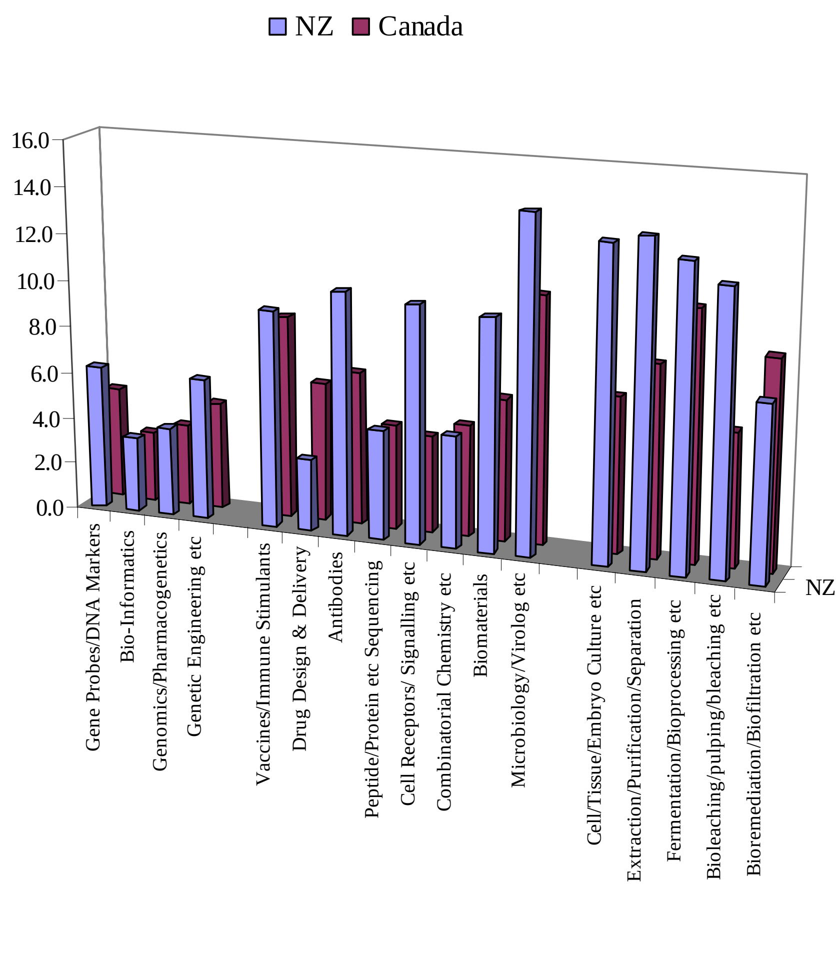
3.4.2 *Age distribution of processes*

Data on the age distribution of biotech processes provides useful information on the development of the biotech industry over time and may also be compared with similar data from overseas. Average age in use in New Zealand is longer than in

Canada for all but two process categories (see Figure 5), possibly because of the lower number of new entrants in New Zealand.

There are distinct differences between modern and older biotechnology processes. Genomics exhibits a typical age structure for a recent process; 56% have used this process for 5 years or less, 83% have used it for 10 years or less. Extraction/purification/separation is typical of a more mature technology; 24% started using this process within the last 5 years (often these are new enterprises). A further 24% have been using this process for at least 20 years. See Figure 6 and Figure 7.

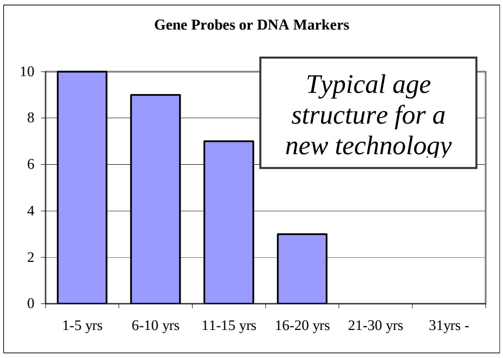
Figure 5 Number of Years Biotechnologies Used in Canada and New Zealand

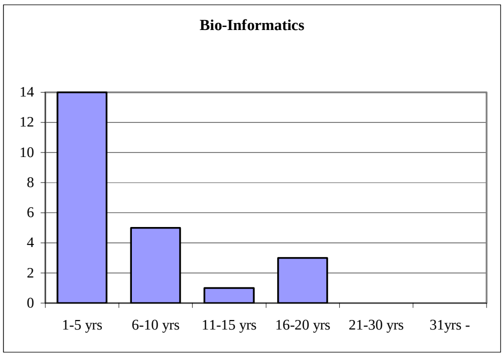


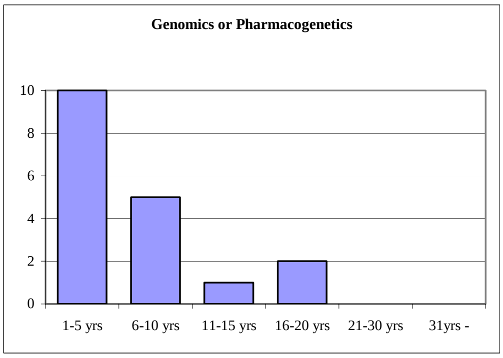
Source: Marsh (2002), McNiven (2001b, p. 11).
Note: Data for New Zealand is drawn from the 2000/01 survey; adjusted for survey year.

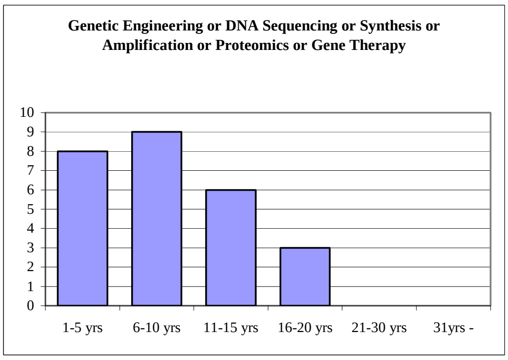
Figure 6 Age Distributions for Selected Biotech Processes

DNA based processes

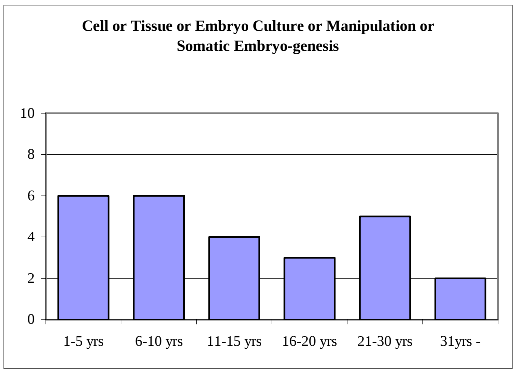


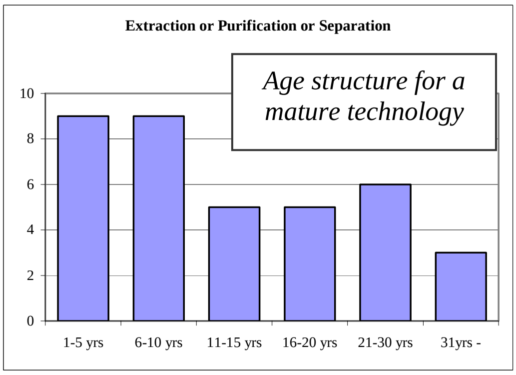






Bioprocessing based processes





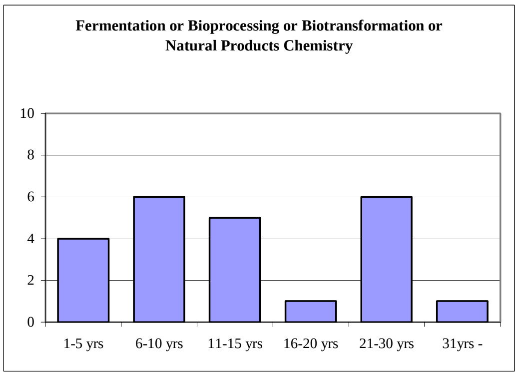
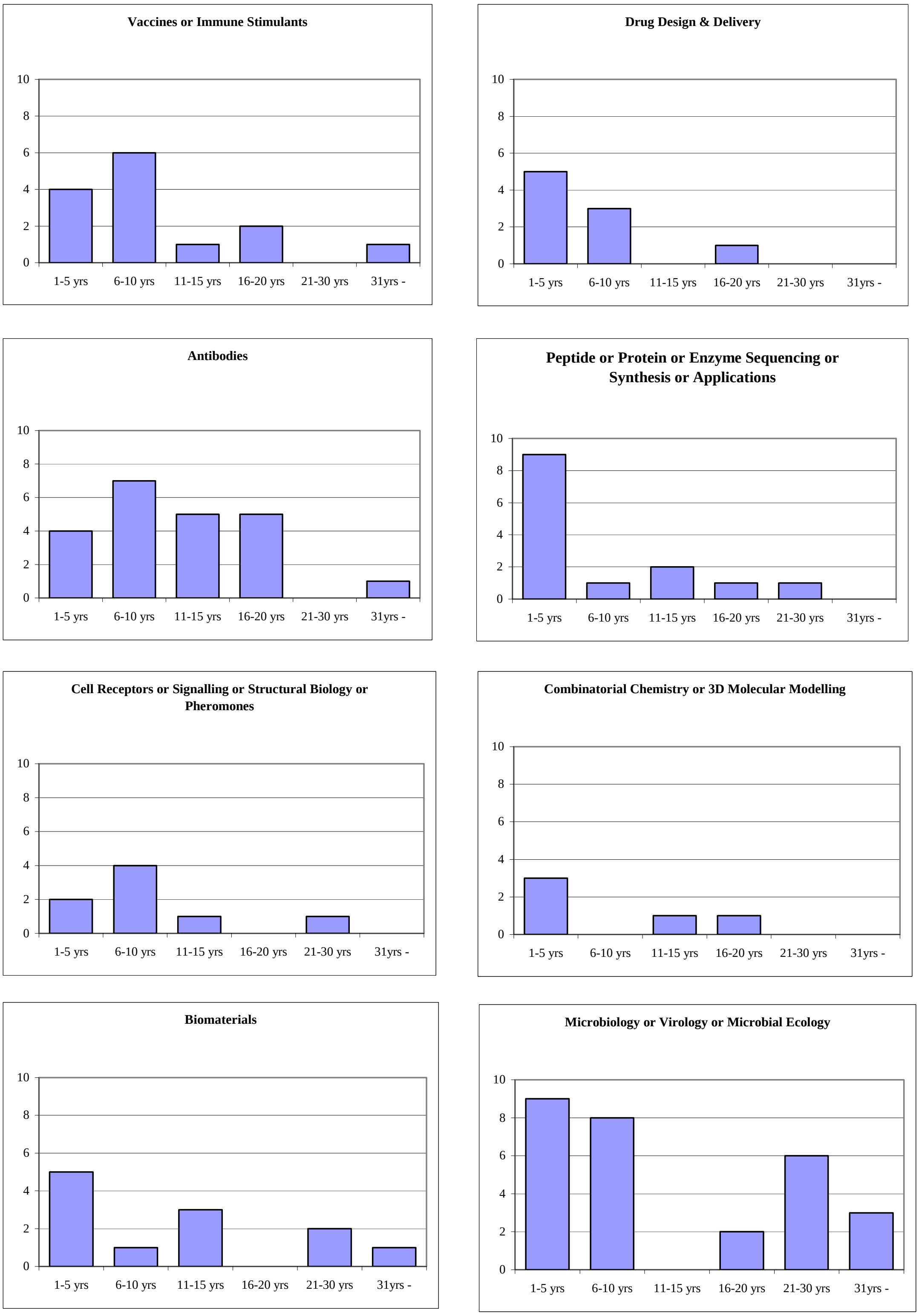


Figure 7 Age Distributions for Selected Biotech Processes

Biochemistry/Immunochemistry based processes



4 Enterprise Size

4.1 Expenditure data

4.1.1 Data from the 1998/99 Survey

Respondents to the 1998/99 survey estimated that income of $475 million was attributable to 'biotechnology activity', in the year ended June 1999 - $326 million from private sector respondents, $149 million from the public sector. This compares to respondents' income from all sources of $7.25 billion i.e. overall biotech provided around 7% of income for the 180 biotech using enterprises[20].

Various difficulties associated with the data on income and expenditure mean that these estimates should be treated with caution. Enterprises were asked to estimate the proportion of their total income and expenditure that could be attributed to biotechnology. Such an instruction is open to widely varying interpretations[21], so for example dairy product manufacturers' estimates varied between zero and 100% of their income.

Fifteen percent of enterprises which use biotech processes reported that they received no income attributable to biotechnology. Seventy three percent received less than 50% of their income from biotech, while 15% attributed *all* of their income to biotech. Within the MBE group 53% received 0 > 25% of their income from biotech, while 15% (around 9 enterprises) received *all* of their income from biotech – such firms are commonly termed Dedicated Biotechnology Firms (DBF) in the international literature, see Table 11 below.

[20] Expenditure of $405 million was attributable to biotech activity; 6% of total expenditure ($6312 million).

[21] depending on interpretation of 'attributable' and whether the respondent concentrated only on *modern* biotech. Based on a broad interpretation it could be said that *all* dairy manufacturing income is attributable to biotech. Separation of the proportion of this attributable to *modern* biotech would be very difficult. These issues are also discussed in Statistics New Zealand (2001) and Marsh (2001b).

Table 11 Biotech Income as a Percentage of Total Income (1998/9)

Percentage of Income from Biotech	All Groups	Modern Biotech Enterprises
0	15%	5%
0 > 25%	47%	53%
25 > 75%	17%	16%
75 > 100%	5%	11%
100%	15%	16%

Source: Marsh (2001a, p. 22)

4.1.2 *Data from the 2001/02 Survey*

The 2001/02 survey, conducted by the author (Marsh, 2002), was addressed to organisations thought to be conducting R&D using modern or traditional biotech processes; a different survey population to the 1998/99 survey. It provides data on some expenditure variables not included in the 1998/99 survey e.g. R&D expenditure, biotech R&D expenditure and revenue from new biotech products/processes. Estimates in Table 12 and Table 13 have been obtained by adjusting category totals based on the response rate in each category[22]. These estimates are subject to wide confidence limits and so should be used with caution.

[22] For example response rate in the non-food manufacturer's category was 67%. Total R&D expenditure for all respondents was \$9.7 million. Estimated R&D expenditure for all non-food manufacturers (that conduct biotech R&D) is \$9.7m/0.67=\$14.47m

Table 12 Expenditure and Revenue Estimates 2001/2 ($ millions)

Industrial Group	Expenditure 2000/01	Revenue/ Sales 2000/01	R&D Expenditure 2000/01	% Expenditure on R&D
Primary Products	27	33	3	13%
Food Manufacturing	4,566	5,384	70	2%
Non-Food Manufacturing	103	179	14	14%
Scientific Research	668	553	478	72%
Tertiary Education	101	61	45	45%
Health Services & Other	619	623	3	1%
Total	6,085	6,833	616	10%

Source: Marsh (2002)
Note: These are population estimates for all biotech enterprises conducting R&D. Estimates for scientific research and tertiary education are based on responses for sub-units and so refer only to the parts of those organisations engaged in biotech research.

Respondents indicated that R&D constituted around 10% of total expenditure; the proportion varying from a high of 72% in the scientific research group to a low of 1-2% for food-manufacturers, health services and other. Respondents spend far more on R&D than the industry average; the dairy industry is reported to spend around 1% of turnover on R&D[23], while R&D expenditure as a proportion of value added of manufactured products was 1.3 percent in 1999/2000 (Ministry of Research Science and Technology, 2002, p. 17).

Table 13 Biotech R&D Expenditure Estimates 2001/2

Industrial Group	Biotech Expenditure 2000/01	Biotech Expenditure as % of Total Expenditure	Biotech R&D expenditure 2000/01	Biotech 'New Revenue'[24]
Primary Products	4	16%	2	12
Food Manufacturing	20	0%	14	56
Non-Food Manufacturing	69	67%	13	13
Scientific Research	268	40%	266	8
Tertiary Education	20	20%	16	0
Health Services & Other	9	1%	3	1
Total	390	6%	313	91

Source: Marsh (2002)
Note: These are population estimates for all biotech enterprises conducting R&D.

[23] The dairy industry (dominated by Fonterra) is reported to spend "in excess of 1% of it's annual turnover on R&D; in excess of $100million per year" Marshall (2001).

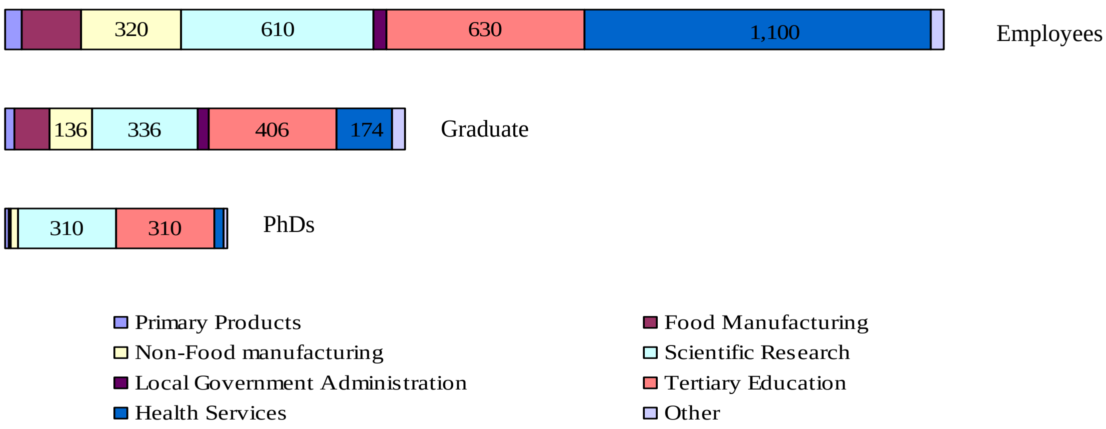
[24] From biotech products/processes introduced in the last 3 years

Biotech expenditure in 2000/01 was estimated to be around $390 million; this can be compared with an estimate of $260 million for 1998/99[25]. These estimates are consistent with the sector growth rate of around 20% per annum reported by some industry observers[26] (Ernst & Young, 2003). Expenditure on biotech R&D ($313 million) comprised around 80% of all biotech expenditures.

4.2 Human Resources data

Respondents to the 1998/9 survey were asked to provide data on their employees 'supporting biotech activity'. They were specifically asked *not* to include staff performing indirect support to biotech activities e.g. central finance or personnel or other similar centralised support services.

Figure 8 Number of Biotech Employees by Qualification and Industrial Group



Source: Marsh (2002)

Survey respondents reported that a total of 3057 (or 2984 full time equivalent) staff supported biotech activity. Around 67% were graduates and 26% had PhDs. The largest employee group came from the health services industrial group, followed by the tertiary education and research groups (see Figure 8).

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[25] Biotech expenditure by all respondents in MBE and TBE groups – Marsh (2001) Unpublished Results from Further Analysis of the 1998/99 Survey data.

[26] Growth from $260m in 1998/99 to $390m in 200/01 indicates a growth rate of 22.5% per annum.

Most graduates were employed by the tertiary education and research groups (most health services biotech employees are not graduates). The concentration of qualified staff is most marked for staff with PhDs – 88% of these were employed within these two groups. MBEs employed 1667 biotech staff (FTE) – 56% of the total for all respondents. Employment of qualified staff was heavily concentrated in MBEs; they employed 83% of biotech graduates and 95% of PhDs.

The 20002 survey provides data on the number of employees engaged in biotech R&D; this variable was not included in the 1998/99 survey. Estimates in Table 14 and Table 15 have been obtained by adjusting category totals based on the response rate in each category[27]. These estimates are subject to wide confidence limits and so should be used with caution.

Table 14 No. of Employees (2002)

Industrial Group	All Employees	Biotech Employees						
		PhD	MSc or MPhil	BSc or BTech	Diploma or Cert	Other Qual	No Qual	Total Biotech Staff
Primary Products	624	27	24	68	14	11	97	241
Food Manufacturing	21,568	26	21	174	205	16	211	653
Non-Food Manufacturing	639	33	21	185	60	7	115	421
Scientific Research	5,022	527	129	517	85	22	32	1,298
Tertiary Education	1,502	243	107	227	21	20	14	632
Health Services & Other	11,863	37	7	26	2	2	-	74
Total	41,218	893	309	1,196	387	78	469	3,318

Source: Marsh (2002)
Note: These are population estimates for all biotech enterprises conducting R&D

The 2002 estimate of 3,318 biotech staff may be compared with a head count of 2053 reported for June 1999[28]. These estimates are also consistent with the high sector growth rate mentioned in above.

[27] See footnote 22 for estimation method.

[28] Headcount at June 1999 for all respondents in MBE and TBE groups – Marsh (2001) Unpublished Results from Further Analysis of the 1998/99 Survey data.

Table 15 No. of Employees Engaged in Biotech R&D 1999 and 2002

Industrial Group	1999	2002
Primary Products	95	116
Food Manufacturing	42	68
Non-Food Manufacturing	51	75
Scientific Research	978	1,227
Tertiary Education	463	527
Health Services & Other	33	30
Total	1,661	2,044

Source: Marsh (2002).
Note: These are population estimates for all biotech enterprises conducting R&D

Respondents to the 2002 survey indicated that around 60% of all 'biotech staff' were engaged in R&D. The number of staff engaged in R&D increased from around 1660 in 1999 to 2044 in 2002, indicating growth of around 7% per annum.

5 Innovation Output

5.1 Product and Process Development

One indication of the rate of innovation by biotech respondents is provided by questions such as: "In the last 3 years, how many new or significantly improved products or processes has this business introduced on to the market?"

Overall, 51% of respondents to the 2002 survey reported implementation of a new *product* with the innovation rate being lowest for food manufacturers (33%) and highest for non-food manufacturers (79%). Process innovation rates were much lower with only 21% reporting implementation of a new *process* in the last 3 years; this is notably different to the 98/99 survey when 33%[29] of enterprises reported introduction of new products and the same percentage reported introduction of new processes[30]. Enterprises were also asked about products and processes under development. Innovation rates were rather higher for this question

[29] The higher innovation rate reported in the 2002 survey (51%) is expected since it was targeted at enterprises that conduct R&D.

[30] Future work is required to better understand the way in which New Zealand enterprises respond to questions on the number of new products and new processes.

with 79% of respondents reporting that they had products or processes under development, see Table 16.

Respondents were asked whether new products/processes were new to their business, new to New Zealand or new to the world. This question aims to elicit an indication of the degree of novelty of the new product/process[31]. Out of 80 new products introduced in the last 3 years, 91% (73) were reported to be new to New Zealand and 66% (53) new to the world, see Table 17. The proportion reported to be new to New Zealand or to the world is surprisingly high[32]. One possible explanation is that respondents under reported products that were new to their business only.

The distribution of the new product/process variables is very skewed; for example the top 3% introduced 20% of all new products while the bottom 74% introduced only 19%, see Table 18.

[31] 'New to the world' products/processes are assumed to be most novel.

[32] No data is available from the 1998/99 survey on products new to business, NZ, world. Process data was collected but was processed inconsistently and so is of little use.

Table 16 Innovative Output of Biotech Respondents (2002)

Industrial Group	No. of Biotech Respondents	% Reporting Any R&D	% Implementing New Product Last 3 Yrs	% Implementing New Process Last 3 Yrs	% with products or processes under development
Primary Products	6	83%	67%	17%	67%
Food Manufacturing	6	83%	33%	17%	67%
Non-Food Manufacturing	14	100%	79%	43%	93%
Scientific Research	18	94%	39%	6%	89%
Tertiary Education	12	100%	42%	17%	75%
Health Services and Other	5	40%	40%	40%	40%
Total	61	90%	51%	21%	79%

Note: percentages should be interpreted with caution because of small cell numbers.
Source: Marsh (2002).

Table 17 Number of New Products and Processes in Last 3 years (2002)

	Number of New Products			Number of New Processes		
Industrial Group	New to the Business[33]	New to New Zealand	New to the World	New to the Business	New to New Zealand	New to the World
Primary Products	21	20	14	1	0	1
Food Manufacturing	2	1	1	4	4	0
Non-Food Manufacturing	34	30	19	9	2	2
Scientific Research	12	11	11	1	0	1
Tertiary Education	8	8	7	2	2	2
Health Services and Other	3	3	1	2	0	0
Total	80	73	53	19	8	6

Source: Marsh (2002).

[33] This is also the ‘total’ number of new products introduced. Products that are ‘new to the world’ are also recorded as being ‘new to NZ’ and ‘new to the business’.

Table 18 Frequency Distribution for Number of New Products and Processes 2002

Number of Products/ Processes Planned	New Product Last 3 Yrs		New to New Zealand	New to World	New Process Last 3 Yrs	
0	30	49%	33	52	48	79%
1	15	25%	13	6	10	16%
2-5	11	18%	10	1	3	5%
More than 5	5	8%	5	2	0	

Source: Marsh (2002).

5.2 International Comparisons

Innovation rate data have been collected in EU and OECD member states since 1992[34] but was not systematically collected in New Zealand until 2001. Some data are available from an innovation survey commissioned by MORST in 1994. Respondents were asked: "how many completely new product lines have you introduced in the last 5 years?" It was found that the average company had introduced 16 completely new products over that period (Frater, Stuart, Rose, & Andrews, 1995, p. 74). This is a significantly higher level than reported by biotech respondents, (averaging one new product per enterprise over the last three years) although this may be partly attributable to differences in the survey populations, question formats and timeframe.

In June 2001, Statistics New Zealand conducted the first economy wide Business Practices Survey (BPS). The BPS collected information on three aspects of business activity: use of information technology, innovation and management practices (Statistics New Zealand, 2002). Key findings included:

> Sixty-eight percent of New Zealand private sector enterprises introduced an innovation in the three years ended June 2001. Forty-two percent of firms introduced both product and process innovations, while a smaller proportion introduced product-only innovations (19 percent), and process-only innovations (7 percent).
>
> The proportion of New Zealand firms that introduced an innovation increased with business size. Eighty percent of large firms (those with 50

[34] The European Community Innovation Surveys (CIS) began in 1992 and were repeated in 1996 and 2001(Archibugi, Cohendet, Kristensen, & Schaffer, 1994; Eurostat, 2001), for details of OECD innovation surveys see Muzart (1998).

> or more full-time employees) introduced an innovation, compared with 66 percent of small firms (those with 6 to 19.5 full-time employees).
>
> The manufacturing sector had the highest rate of innovation in the economy (79 percent of firms). In particular, 87 percent of firms in the petroleum, coal and chemical manufacturing industry introduced an innovation. Fifty-six percent of firms in the primary sector introduced an innovation, and 67 percent of firms in the services sector introduced an innovation.

The OECD has used 'the share of firms introducing at least one new or improved product or process onto the market over a given period' to compare the innovative output of firms in different member countries. The OECD average proportion of manufacturing firms that introduced a new product or process in 1994-96 was 56% (data from 21 OECD members). For firms with 20-49 employees the share was significantly lower, averaging 41% of firms (OECD, 2001, p. 174). Statistics New Zealand (2002) reports that:

> the level of innovative activity carried out by New Zealand enterprises is at least equal, if not higher, than that indicated in a survey of European Union (EU) countries. The level of innovation in the New Zealand manufacturing and services sectors (the EU survey excluded the primary sector) was higher than that of all EU countries.

Review of the innovation literature suggests that Statistics New Zealand should be cautious of claiming that "the level of innovation in the New Zealand manufacturing and services sectors …was higher than that of all EU countries" on the basis of one set of survey results. For example Tether (2001, p. 17) reports that comparisons between sectors and between countries are problematic:

> For although the aim of CIS is to provide comparable statistics (between countries and sectors), there are doubts as to whether the findings are comparable. Are services really less likely to be (technological) innovators than manufacturers? – perhaps they are merely less likely to recognize themselves as innovators. Statements about the proportion of innovators also say nothing about the intensity of innovation activities, which tend to be unevenly distributed among firms and groups of firms. Meanwhile the threshold of what is considered an 'innovation' may vary between sectors and countries. A small change may not qualify as an innovation in a sector where change is routine or continuous, but may be considered an innovation where change is rare.

New Zealand government, business and the media have been heavily preoccupied with the word innovation over the last few years. The word tends to be used in a loose sense and it is reasonable to assume that many respondents will have been predisposed to regard quite small changes to their business as 'innovations'. A detailed investigation into the kinds of activities that respondents in New Zealand

and other countries regard as being innovations is required before definite conclusions can be reached on the relative innovative output of New Zealand firms.

The mean innovation rate for a group of small OECD countries that New Zealand might wish to emulate[35] was 62% for all firms and 50% for small firms. The 1998/99 biotech survey found that 45% of respondents had introduced an innovation in the previous 3 years, while the 2002 survey found that 54% were innovators. The low level of reported innovation, relative to the BPS may, in part, be explained by the nature of the sector where a high proportion of enterprises[36] are engaged in scientific research or higher education where the main outputs may be intellectual property in the form of journal publications and patent applications. It is also possible that enterprises in a research-intensive sector such as biotech are less likely to classify changes as innovations, compared to less research-intensive sectors.

Further work is required before definite conclusions can be reached on the relative innovative output of New Zealand biotech firms – although the evidence reviewed above suggests that New Zealand biotech firms do not have a particularly high rate of new product or process development relative to other New Zealand sectors or to other countries.

[35] Austria, Belgium, Denmark, Finland, Ireland, Netherlands, Portugal, Sweden, Switzerland

[36] 38% of institutions responding to the 2002 survey fell into these two groups (25% for the 1998/9 survey).

6 Patenting and the Stock of Ideas

The use of patents as economic indicators has been well established for many years[37]. Ideally we might hope that patents would provide an indication of the rate at which the production possibilities frontier is shifted outward (Griliches, 1990, p. 1699). In practice they are most commonly used as indicators of innovative activity, although more strictly defined they are indicators of *invention* not necessarily leading to innovation.

Patent statistics have also been used to test Romer's (1990) model of endogenous technological change. In this model productivity growth is driven by allocation of resources to an ideas-producing sector and ideas sector productivity must increase proportionately with the stock of ideas already discovered. Patent statistics have been used as an indicator of the stock of ideas by Porter and Stern (2000), among others. There is also a rapidly increasing literature in the biotechnology area based on analysis of patents (Foltz, Barham, & Kim, 2000; Joly & de Looze, 1996; Malo & Geuna, 1999; McMillan, Narin, & Deeds, 2000).

Analysis of New Zealand patenting activity in biotechnology was carried out by the author, using international applications published in the Patent Cooperation Treaty (PCT) Electronic Gazette. The PCT provides for the filing of an international application to have the same effect as a national application in each of the contracted states designated in the application (OECD, 1994, p. 19); it thus provides a useful measure of international patenting activity. Use of applications data provide a more immediate picture, since it can take up to five years from the first application for a patent to be granted.

Methodology based on Engelbrecht and Darroch (1999) was used to compare New Zealand's rate of patenting with G7 and a reference group of small high-income OECD countries (see Table 19 and Figure 10). For the purposes of this analysis the International Patent Class C12N is assumed to provide a good indication of the level of modern biotech activity.

[37] See Griliches (1990) for a comprehensive survey.

Table 19 New Zealand and OECD Patenting Rates in Biotechnology

	1997-99	2000-02	% Change 97/99-00/02	1998-2002
OECD (18 Countries)	3.9	5.9	51%	5.3
G7	3.9	5.9	52%	5.3
Small Countries[38]	4.4	6.1	40%	5.5
Australia	3.5	4.7	34%	4.1
New Zealand	2.0	4.8	145%	3.7

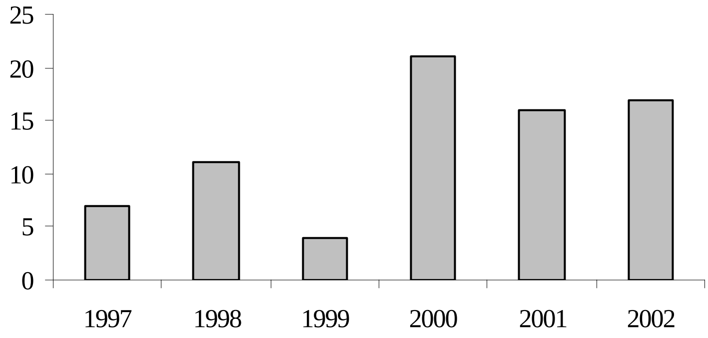
Source: Original analysis of PCT database by the author.
Notes: Patenting rates are for class C12N per million population per year.

New Zealand's rate of modern biotech patent applications over the five years to the end of 2002 was 3.7 per million of population, per year. This is below the average for the G7 (5.3) and for a reference group of small, developed OECD economies (5.5). Patent application rates range from a high of 15.2 for Denmark to a low of 0.5 for Italy. Overall New Zealand ranks eleventh out of 18 with a patenting rate above that found in France and Japan. However New Zealand's performance is disappointing compared to other small countries with strong primary industries that it might hope to emulate e.g. Denmark (15.2), Switzerland (10.9), Netherlands (5.5), Australia (4.1).

Comparison of the three-year periods 1997-99 and 2000-02 reveals an average increase in patenting rates of 51%. Patent application rates increased in all countries, with the rate of increase varying from 18% in the Netherlands to 145% in New Zealand (see Figure 9). New Zealand has increased its performance relative to the OECD and Australia; although the rapid change in patent application rates may, in part reflect an increased propensity to patent caused by institutional change in the science system.

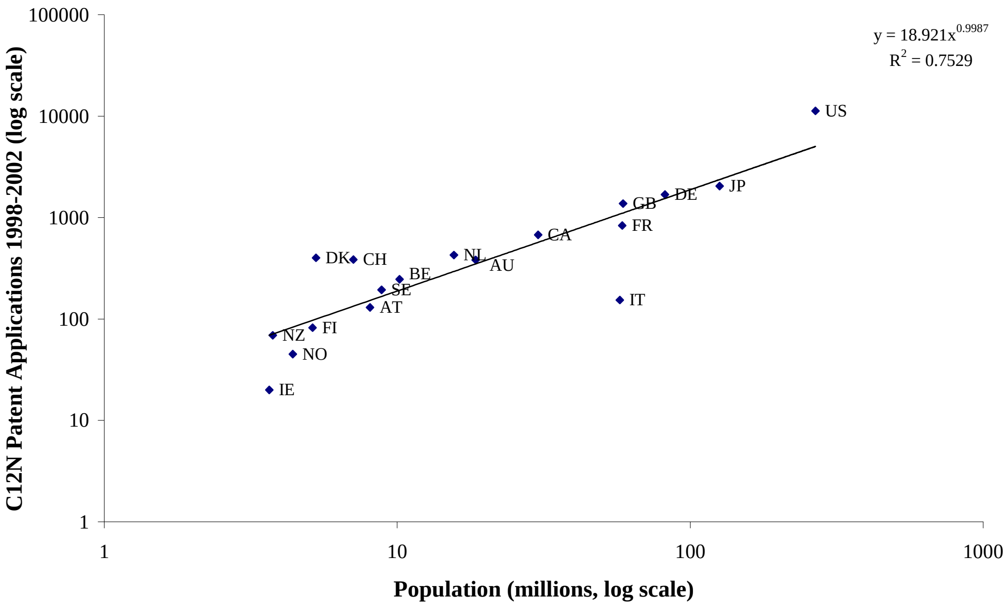
[38] Australia, Belgium, Denmark, Finland, Ireland, Netherlands, NZ, Norway, Sweden, Switzerland

Figure 9 New Zealand C12N Patent Applications



Source: Original analysis of PCT database by the author.

Figure 10 Comparison of International Biotech Patent Application Rates



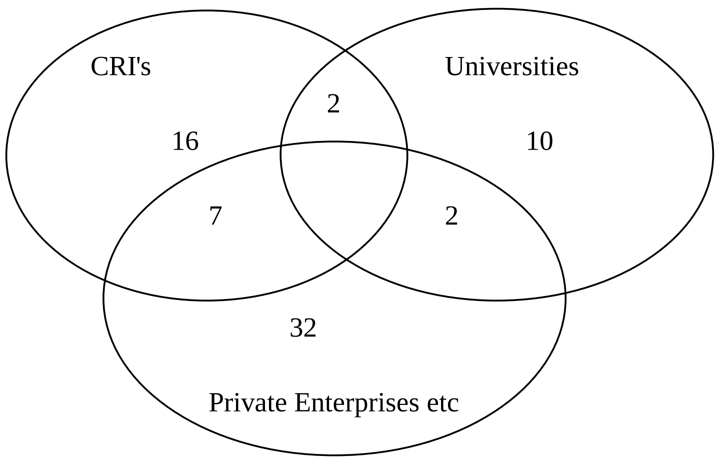
Country Codes (in patent rate order): Denmark (DK), Switzerland (CH), United States (US), Netherlands (NL), Belgium (BE), United Kingdom (GB), Canada (CA), Sweden (SE), Australia (AU), Germany (DE), New Zealand (NZ), Japan (JP), Austria (AT), Finland (FI), France (FR), Norway (NO), Ireland (IE), Italy (IT).

Source: Original analysis of PCT database by the author.

Figure 10 uses log scales to compare international C12N patenting rates, adjusted for the population of each country. It can be seen that this produces a surprisingly good fit with 75% of the variation in applications being explained by population size. Based on this analysis New Zealand is very close to the trend line; its C12N patent rate is close to the expected value, after adjusting for population size. There are few real outliers, although Denmark and Switzerland have a rather higher patenting rate than expected, while the rate for Italy and Ireland is lower than expected.

A breakdown of New Zealand patent applications by organisational type indicates that C12N patenting activity is heavily concentrated in a small number of organisations. Five organisations[39]; a private company (Genesis), two CRIs (AgResearch and HortResearch) and two universities (Auckland and Otago) accounted for 75% of patenting activity over the five years to the end of 2002. Figure 11 illustrates the distribution of patenting activity across the main organisational types. It can be seen that joint patents accounted for 16% of the total, with collaborations between CRIs and private enterprises being most common.

Figure 11 No. of Patent Applications 1998-2002, by Organisational Type



Source: Original analysis of PCT database by the author.
Notes: Joint patent applications were also observed within organisational types e.g. between universities and between different private enterprises.

[39] Either individually or in partnership with others.

Organisations participating in the 1998/99 and 2002 biotech survey were asked whether they had made 'biotech related patent applications' and so reported on a wider range of patents falling under C12N and several other patent classes. As would be expected from the data presented above, patenting activity was concentrated in a relatively small number of organisations, see Table 20.

Table 20 Patent Applications

	1998/99	2002
No. of Respondents	180	61
No. respondents making patent applications in last year	21	22
Total No. of patent applications	56	69

Sources: Marsh (2001a; 2002).

7 Partnerships and Alliances

7.1 Data from the 1998/99 Survey

Respondents to the 1998/99 biotech survey were asked[40] about partnerships and alliances for biotechnology activity over the last 3 years. Further questions focussed on the purpose of any alliances and the types of New Zealand and overseas organisations involved.

52% of biotech respondents reported a partnership/alliance with a total of 303[41] different organisation types; this suggests that the 93 respondents that had alliances had an average of at least three partners each.

The proportion of respondents reporting a biotech alliance varied markedly between industry groups from 100% in tertiary education to a low of 18% for local government. Overall 48% reported at least one New Zealand alliance while 30% reported an overseas alliance. Overseas alliances were most common in the tertiary education, non-food manufacturing and scientific research groups, see

[40] "In the last 3 years did this business have any partnership/alliance for undertaking biotechnology activity (research or production)?"

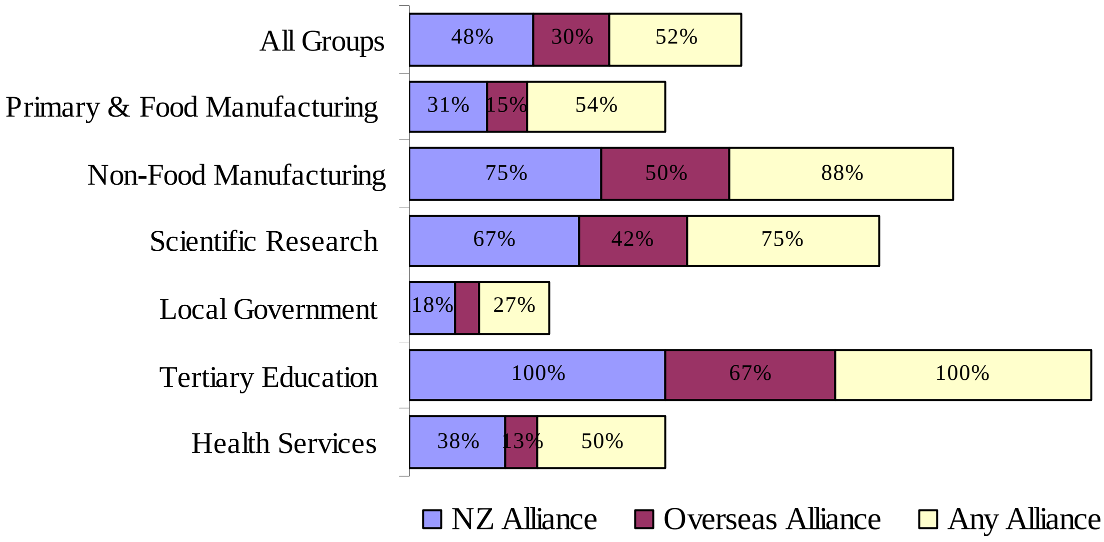
[41] Respondents were not asked how many different organisations they had partnerships with. Data was collected on the different *types* of organisations with which they formed alliances e.g. CRIs businesses, universities etc both in NZ and overseas.

Figure 12. A breakdown of alliance frequency by biotech category reveals that 90% of MBEs reported alliances falling to 42% for MBUs and 24% for TBUs.

The most commonly reported alliance purposes were product or process development; reported by 81% of respondents who had an alliance and clinical/field trials (48%). 13% reported alliances for the purpose of undertaking basic research[42], see Figure 13.

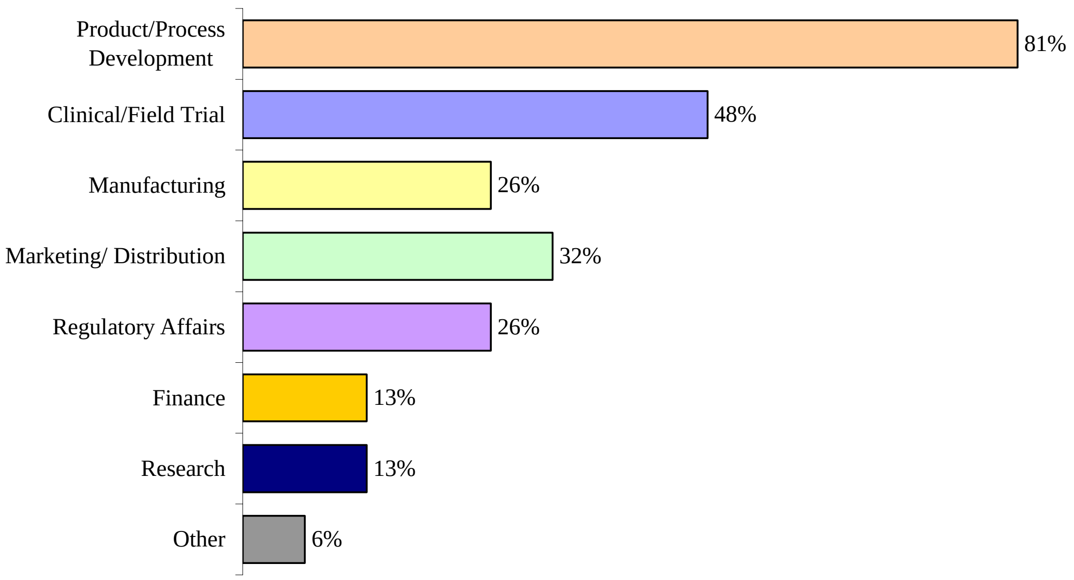
[42] Based on answers in the 'other' category - this may be an underestimate since the questionnaire did not include a basic research option.

Figure 12 Percentage of Respondents Reporting Biotech Alliances (1998/99)



Source: Marsh (2001a, p. 17)

Figure 13 Purpose of Biotech Alliances (1998/99)



Source: Marsh (2001a, p. 18)

7.2 Data from the 2001/02 Survey

84% of respondents to the 2001/02 survey reported a biotech partnership or alliance with a total of 406 different organisations. The higher incidence of alliances compared to the 1998/99 survey was expected, given the different characteristics of the survey population. While most enterprises (88%) reported up to 10 alliances; two organisations reported 90 and 50 different alliances respectively[43], see Table 21.`

Table 21 Frequency Distribution for No. of Alliances

Number of Alliances	
1-3	51%
4-10	37%
10+	12%

Source: Marsh (2002).

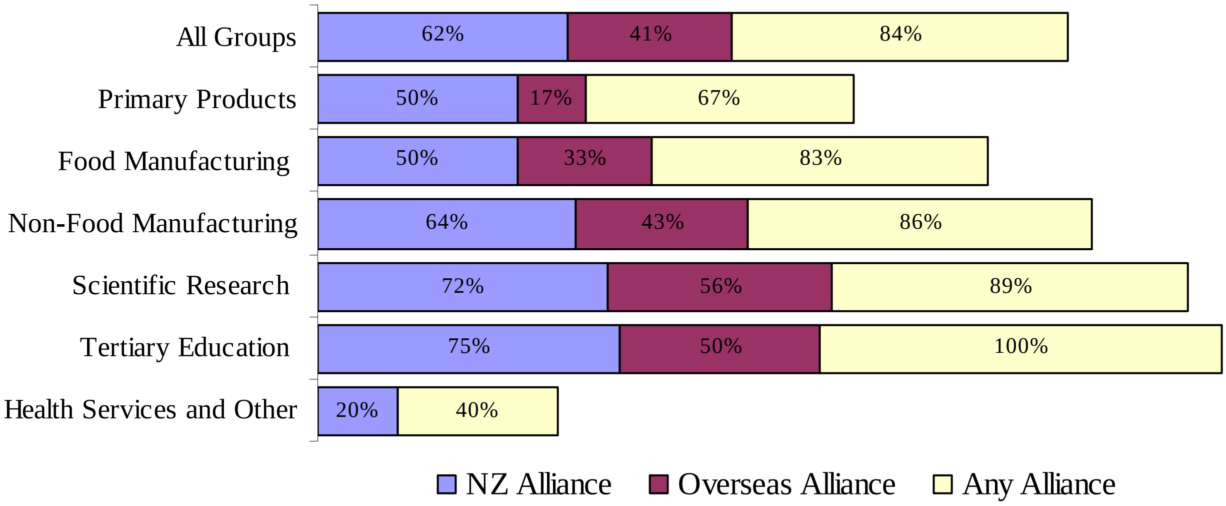
The proportion of respondents reporting a biotech alliance was high in all industry groups, varying from 100% in the tertiary education group to 40% for 'health services and other' (a small group including some enterprises that did not conduct significant R&D).

Overall 62% reported at least one New Zealand alliance while 41% reported an overseas alliance. Overseas alliances were most common in the tertiary education, and scientific research groups, see Figure 14.

The most commonly reported alliance purposes were product/process development – reported by 82% of respondents who had an alliance and basic research (74%), see Figure 15. A higher proportion of alliance partners were engaged in basic research than reported in the 1998/99 survey. This can be explained by differences in the survey population and the lack of a specific question about basic research in the earlier survey.

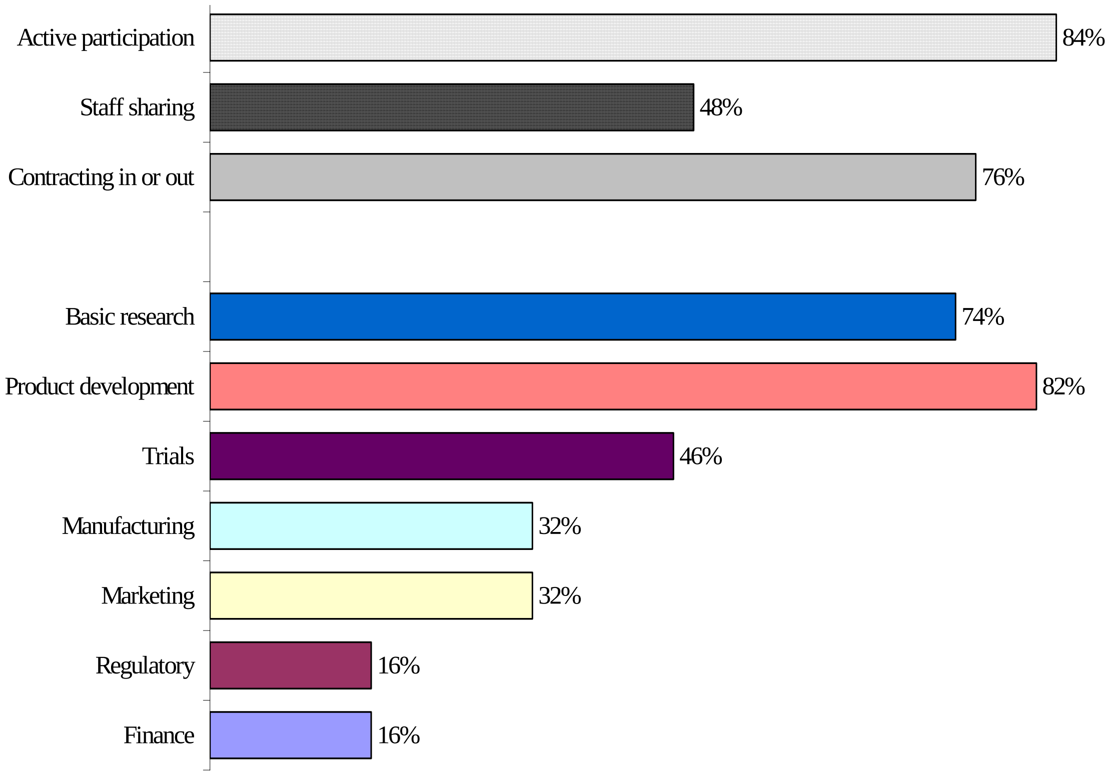
[43] A university 'sub-unit' with around 100 staff conducting R&D reported 90 different 'partnerships or alliances'; many of these are 'academic collaborations'.

Figure 14 Percentage of Respondents Reporting Biotech Alliances (2002)



Source: Marsh (2002)

Figure 15 Alliance Type and Purpose

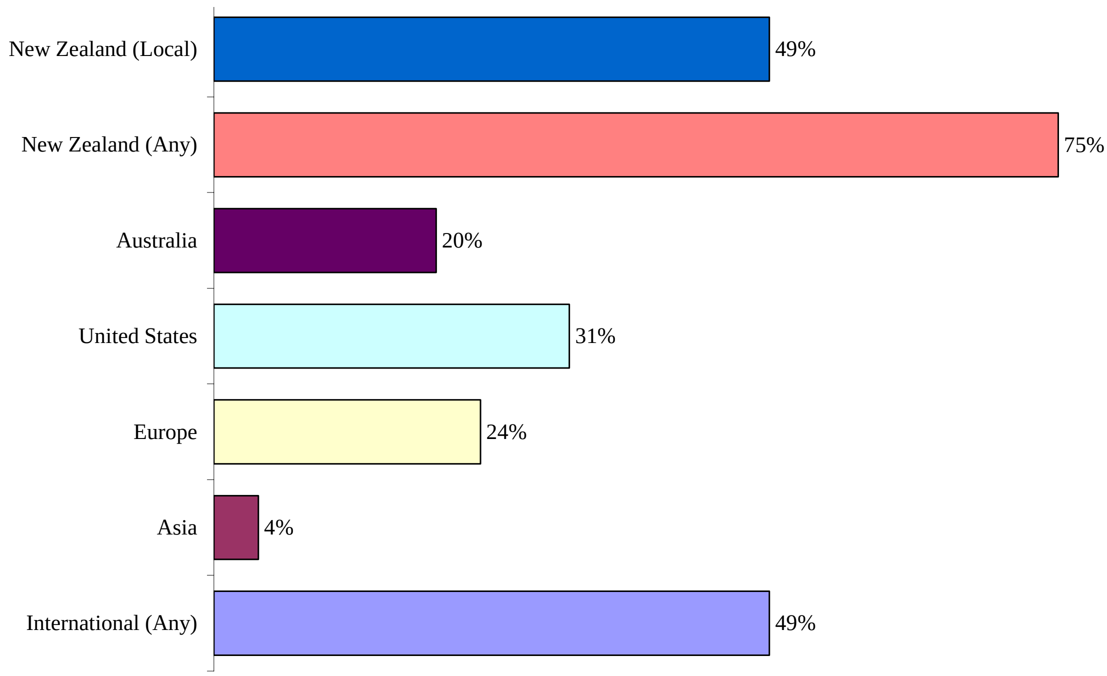


Source: Marsh (2002).
Note: Percentages expressed as % of number of enterprises with an alliances.

A high proportion of alliances had characteristics that would indicate active and substantive partnerships. 84% of respondents (with alliances) reported that at least one alliance involved 'active participation by both parties', 76% had alliances involving 'contracting in or out' and 48% had alliances involving 'staff working or training at partner locations', see Figure 15.

Respondents were asked to report on the key characteristics of their three most important partnerships; 55% of these involved New Zealand partners, followed by 19% USA, 14% Europe, 9% Australia[44]. Figure 16 summarises data on the percentage of respondents with at least one alliance in different countries.

Figure 16 Percentage of Respondents with Alliance Partners, by Country



Source: Marsh (2002). Notes: Percentages expressed as % of number of enterprises with an alliance. International (Any) excludes Australia.

Most alliance partners were universities/polytechnics (32%), larger firms (27%), smaller firms (17%) or CRIs (16%)[45].

[44] Based on data for 117 different partnerships/ alliances, from 50 respondents with partnerships/ alliances.

Partnerships were established between 1956 and 2001. 54% of partnerships had been established in the last 3 years; providing some support for the observation that partnership activity has increased in recent years[46].

Respondents were asked to rate 'partnership outcomes to date'; 50% were described as 'very productive' and 44% as 'somewhat productive'. Only 6% were reported to be 'not very/not at all productive', see Table 22. The relationship between perceived alliance productivity and other variables is explored in Chapter 6.

Table 22 Alliance Outcomes

Industrial Group	Very Productive	Somewhat Productive	Not Very Productive	Not at all Productive	No. of Alliances
Primary products	60%	40%	0%	0%	5
Food manufacturing	56%	33%	0%	11%	9
Non-food manufacturing	52%	41%	7%	0%	27
Scientific research	52%	43%	2%	2%	44
Tertiary education	48%	45%	7%	0%	29
Health services & other	0%	100%	0%	0%	3
Total	50%	44%	4%	2%	117

Source: Marsh (2002).
Note: Based on up to three of 'the most important partnerships' per respondent.

[45] See footnote 44.

[46] This result is based on a subset of the data; respondents reported year of formation for only 50 out of 117 of the 'three most important partnerships/alliances'.

8 Information Sources

One of the more detailed investigations into information sources for technological learning in New Zealand was carried out by the Foundation for Research Science and Technology (FRST) in 1996/97[47]. The review sought to identify ways in which government could accelerate and enhance technological learning. It was based on 500 personal interviews and 666 mail survey responses. The review highlighted widespread concerns about the availability of science and technology information to users:

> Many concerns about access to information relate to the behaviour of science providers (especially CRIs), often in relation to their intellectual property, commercial confidentiality and charging policies…The Review identifies a wide and pervasive trend among user and other stakeholder groups to be more restrictive and less willing to share information. This trend is occurring even in sectors such as agriculture and horticulture with long traditions of open and free exchanges of information and new ideas…There is a view that CRIs (or at least some CRIs) are ignoring small companies in favour of building more commercially profitable relationships with larger businesses (Hodgson et al., 1998, p. 23-4).

The review report describes sources and forms of technological learning and 'learning concerns' separately for 233 'technological learning groups[48]'. The review could usefully have identified a smaller number of broad categories based on key characteristics of technological learning. Such categories might then have been related to industrial groups, learning concerns and other variables.

Unfortunately very little aggregate analysis was ever reported[49]. Qualitative data from selected technological learning groups associated with biotechnology have been used to create Table 23. Unfortunately the qualitative approach adopted in the report does not allow any conclusions to be drawn on the relative importance

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[47] Reported in Hodgson, P., Howe, J., Saunders, R., & Winsley, P. (1998).

[48] "The taxonomy of 233 technological learning groups was developed over time … with this taxonomy being "grounded" in the experiences and perceptions of research end users, rather than being determined *a priori*"(Hodgson et al., 1998, p. 9).

[49] The decision not to aggregate was defended by the authors; "the level of detail achieved in producing the 233 technological learning group summaries at an end user organisational level means it is more appropriate to present the complete material in Annex 6 rather than attempt to generalise the results of the Review in a way that would mask the differentiated nature of learning and diminish the usefulness of the review"(Hodgson et al., 1998, p. 6).

of different information sources. Furthermore data source coverage in different technological groups appears to be patchy; for example private laboratories might be expected to make some use of trade literature and equipment suppliers. This patchiness may perhaps be a consequence of the qualitative methods used in the survey.

Table 23 Technological Learning Sources 1997

Technological Learning Source	Animal Vaccines and Remedies	Drugs and Medicine Manu-facturers	Dairy Food Product Companies	Private Lab-oratories	Private R&D Companies
Customers	✓		✓	✓	✓
R&D Staff	✓	✓	✓	✓	✓
Senior Management	✓		✓	✓	✓
Journals	✓	✓		✓	✓
Trade Literature	✓	✓	✓		
CRIs	✓	✓			✓
Universities	✓		✓	✓	✓
Overseas research institutes		✓			
Overseas Licences		✓			
Suppliers (raw materials)		✓	✓		
Suppliers (equipment)		✓	✓		✓
Research Associations		✓	✓		
Competitors			✓	✓	
Conferences and Trade Fairs			✓		

Source: Hodgson et al., (1998).

Statistics New Zealand’s 2001 Business Practices Survey provides some useful information on the sources of ideas and information used in innovation. One question related to whether innovations relied on internal or external information sources, or both;

> product innovations relied more on external resources than process innovations. Twenty-one percent of product innovators relied on external resources compared with 8 percent of process innovators. Process innovators relied mainly on internal resources (55 percent), while the proportion of product and process innovators relying on a combination of internal and external resources was about the same (just under a third).

The BPS also provides data on the percentage of innovators making use of different information sources, see Figure 117. It can be seen that the most used sources were ‘competitors’, ‘books, trade journals and conferences’ and ‘industry associations’.

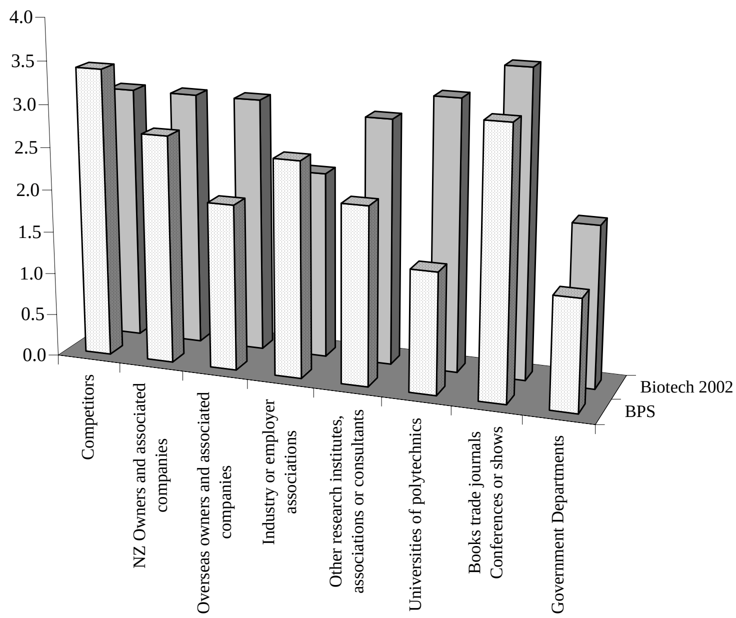
Figure 17 Sources of Information for Innovative Business

Source: Statistics New Zealand (2002, p. 23)

Data on the relative importance of these different sources in all New Zealand firms can be compared with the 2002 Biotech Survey[50], see Figure 18. Biotech respondents ranked the research institutions, universities/polytechnics and ‘books, trade journals and conferences’ more highly than the average for BPS respondents, while BPS respondents ranked industry or employer associations more highly.

[50] Mean scores were created based on Statistics New Zealand category ‘very important’=5, ‘somewhat important’=3, ‘not important’=1. Category descriptions across the two surveys do not exactly match.

Figure 18 Comparison of Information Sources, BPS and Biotech Survey 2002



Sources: Marsh (2002) and Statistics New Zealand (2002).

Table 24 Information Sources, Biotech Survey 2002

	Low 1	2	3	4	High 5	*Not Applicable*	Mean Score
Own staff or staff in parent/subsidiary	0	2	10	16	27	*5*	4.2**
Hiring new staff with required 'know-how'	3	7	12	15	10	*11*	3.5*
Personal contacts with others	2	2	8	19	26	*2*	4.1**
Conferences/workshops/trade shows	3	7	13	25	11	*0*	3.6*
Other Firms	8	7	19	13	4	*7*	3.0
Crown Research Institutes	13	11	16	8	7	*4*	2.7
Other Research Organisations	5	10	23	11	6	*4*	3.1
Universities, Polytechs, research networks	6	9	18	13	10	*3*	3.2
Hospitals	23	9	7	2	1	*17*	1.8
Government departments/agencies	24	11	13	2	1	*8*	1.9
Professional/industry associations	15	16	14	3	2	*6*	2.2
Other organisations			1			*5*	3.0
Academic journals and trade publications	0	3	10	22	25	*0*	4.2**
Library/literature search	2	5	8	24	20	*0*	3.9*
Database retrieval services	5	7	11	15	19	*3*	3.6*
Patent disclosures	15	9	7	9	11	*8*	2.8

Notes: The symbols ** mark sources ranked first to third, * marks sources ranked 4th to 7th. Modal scores for each source are shaded.

Source: Marsh (2002).

9 Other Factors Affecting Innovative Performance

The 2001 survey asked respondents to rank a list of factors “that may affect the amount of innovation produced by your business”, see Table 25. Many of the results are unsurprising; for example ‘quantity of funds available for R&D’ is ranked most highly, followed by ‘number and quality of R&D staff’ and ‘appropriability (ability to profit from the innovation)’.

These mean scores hide some important patterns in the way that respondents answered this question. The most controversial question relates to the impact of ‘one or a few star scientists’; 18 respondents regarded this as being highly important (score 5), while 14 clearly disagreed giving this item a score of 1.

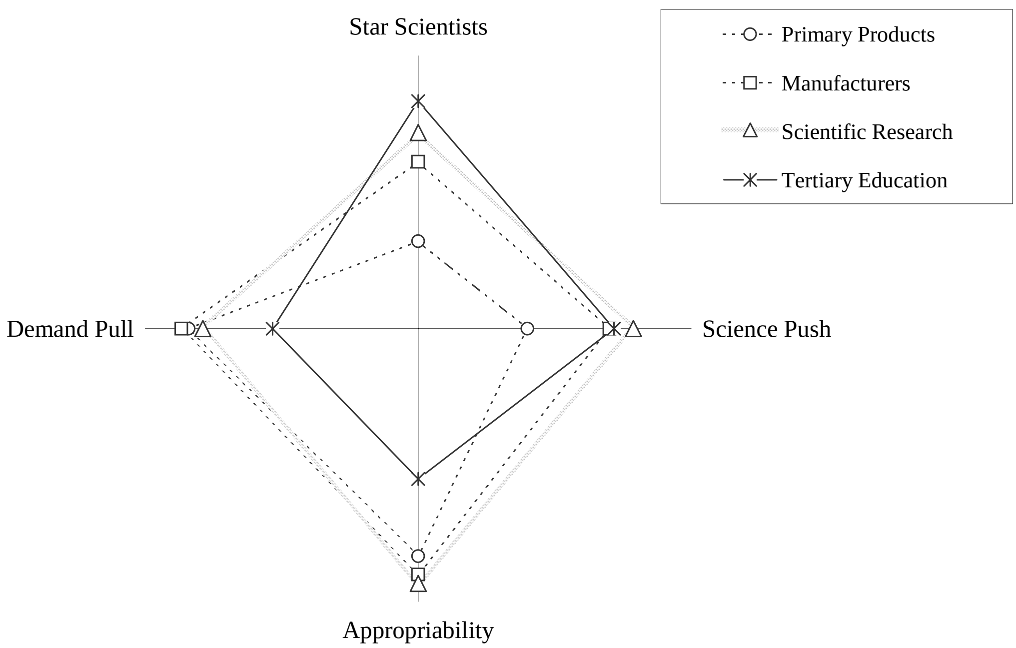
Table 25 Factors Affecting Business Performance 2002

	Low 1	2	3	4	High 5	Mean Score
Conditions in your business						
Quantity of funds available for R&D	1	2	9	16	31	4.3**
Quality of the R&D environment	4	2	9	19	25	4.0
Number and quality of R&D staff	3	3	5	18	28	4.1**
One (or a few) ‘Star Scientists’	14	4	8	12	18	3.3
‘Science push’ or technological opportunity	5	4	16	20	10	3.5
Quality of links with other organisations *in New Zealand*	4	8	23	17	7	3.3
Quality of links with *overseas* organisations	4	5	11	21	16	3.7
Ownership of intellectual property	10	8	9	12	19	3.4
Appropriability (ability to profit from the innovation)	3	5	4	15	31	4.1**
Links with purchasers or consumers e.g. ‘demand pull’	6	7	4	18	21	3.7
Conditions in New Zealand						
Quality/quantity of Basic Science carried out	6	6	13	20	12	3.5
Quality/quantity of Applied Science carried out	5	6	11	23	12	3.5
R&D environment e.g. regulations, incentives, attitudes etc	5	5	13	13	20	3.7

Notes: The symbols ** mark sources ranked first to third,
Modal scores for each source are shaded.
Source: Marsh (2002).

Figure 19 illustrates some of the differences between industrial groups in the perceived importance of different factors. Enterprises in tertiary education place greater weight on 'star scientists' and 'science push' and regard 'appropriability' and 'demand-pull' as less important. By contrast, primary product enterprises rank 'demand-pull' and appropriability as being more important. Mean scores for manufacturers and scientific research organisations were similar for these four factors; perhaps reflecting the importance of commercial incentives for organisations in the scientific research category.

Figure 19 Mean Factor Scores by Industrial Group



Source: Marsh (2002).

10 Summary and Conclusions

10.1 Sector Size and Definition

Different interpretations of the terms biotechnology and biotechnology sector hinder attempts to measure biotech activity in a way that is comparable over time and across nations. Size estimates for the New Zealand biotech sector range from 30 core biotech companies with annual income of the order of $200 million, to many thousands of companies having annual production worth several billion dollars, when traditional food applications such as cheese, yoghurt and beer are included.

The economic literature since the mid 1980s has generally concentrated on modern biotechnology and the biotech sector is often taken internationally to refer to the population of ‘core’ private sector enterprises that conduct R&D into *modern* biotechnology. In this thesis the modern biotech ‘sector’ is defined as the population of private and public sector enterprises that carry out modern biotech R&D. Based on this definition, New Zealand’s modern biotech ‘sector’ consisted in 1998/99 of approximately 57 enterprises, employing around 1700 people. Most activity was concentrated in universities, Crown Research Institutes (CRI) and a small number of private sector companies e.g. Genesis, Virionyx, ViaLactia.

10.2 International Comparisons

The OECD has taken the lead in attempting to develop internationally comparable statistics on biotechnology. Data on public funding of biotechnology and patents were included in its Science, Technology and Industry Scoreboards for 2001 and 2003 (OECD, 2001, 2003) but the variety of definitions and data collection methods make reliable comparisons almost impossible. In the 2003 scoreboard New Zealand is reported to put the highest proportional effort into biotech R&D (biotech R&D as a proportion of total R&D). This results both from New Zealand’s R&D specialisation in the primary sector and from use of a broad definition of what constitutes biotech R&D. Not surprisingly, a rather different picture emerges in absolute terms with New Zealand’s total biotech GBAORD being the third smallest of the 21 countries listed (see section 2.5)

A more accurate international comparison can be made with Canada, based on data from the Statistics New Zealand biotech survey, since this was closely modelled on surveys carried out by Statistics Canada. New Zealand's biotech revenue per million population (NZ$54 million) is rather lower than Canada's (NZ$94 million), but the difference is fairly small considering Canada's higher per capita income and proximity to the United States. New Zealand has a rather lower mean revenue per biotech firm (NZ$5.3m vs. NZ$8.0m); consistent with the predominance of small firms in the New Zealand economy. New Zealand appears to have a significantly higher rate of biotech employment. There is some evidence that use of biotech processes in New Zealand is at an earlier stage with 72% being at the R&D stage against 49% in Canada.

10.3 Sector Characteristics

Enterprises in the modern biotech sector are split fairly evenly between the private sector and the public sector. They reported expenditure on biotech of NZ$202 million and income from biotech of NZ$236 million for 1998/99. This compares to enterprise income from all sources of NZ$2.1 billion i.e. biotech provided around 11% of income for the 57 enterprises. More recent data indicates that annual growth in expenditure may be as much as 20%.

Respondents to the 2002 biotech survey indicated that R&D constituted around 10% of total expenditure while expenditure on biotech R&D comprised around 80% of all biotech expenditures. Around 60% of all 'biotech staff' were engaged in R&D. Respondents spent far more on R&D than the industry average. For example the dairy industry is reported to spend around 1% of turnover on R&D, while R&D expenditure as a proportion of value added of manufactured products was 1.3 percent in 1999/2000 (see section 4.1.2).

The government has been estimated to spend around NZ$127m a year on all biotechnology-related research, ranging from genomics to processing of natural products. Biotechnology-related research comprised around 15% of total government R&D spending in 2000.

Data on the age distribution of biotech processes provides useful information on the development of the biotech industry over time and may also be compared with similar data from overseas. Average age in use in New Zealand is longer than in Canada for all but two process categories, possibly because of the lower number of new entrants in New Zealand. There are distinct differences between modern and older biotechnology processes. Genomics exhibits a typical age structure for a recent process; 56% have used this process for 5 years or less, 83% have used it for 10 years or less. Extraction/purification/separation is typical of a more mature technology; 24% started using this process within the last 5 years (often these are new enterprises). A further 24% have been using this process for at least 20 years (see section 3.3)

10.4 Innovative Output

In June 2001 Statistics New Zealand conducted the first economy wide Business Practices Survey (BPS). The BPS collected information on three aspects of business activity: use of information technology, innovation and management practices (Statistics New Zealand, 2002). Statistics New Zealand (2002) reports that: "the level of innovative activity carried out by New Zealand enterprises is at least equal, if not higher, than that indicated in a survey of European Union (EU) countries". Review of the innovation literature suggests that Statistics New Zealand should be cautious of making such claims on the basis of one set of survey results. For example Tether (2001, p. 17) reports that comparisons between sectors and between countries are problematic for a number of reasons (section 5.2).

One indication of the rate of innovation by biotech respondents is provided by questions such as: "In the last 3 years, how many new or significantly improved products or processes has this business introduced on to the market?" Overall, 51% of respondents to the 2002 biotech survey reported implementation of a new *product* with the innovation rate being lowest for food manufacturers (33%) and highest for non-food manufacturers (79%). Process innovation rates were much lower with only 21% reporting implementation of a new process in the last 3 years; this is notably different to the 1998/99 survey when 33% of enterprises reported introduction of new products and the same percentage reported introduction of new processes.

Further work is required before definite conclusions can be reached on the relative innovative output of New Zealand biotech firms, although the evidence reviewed in section 5.2 suggests that New Zealand biotech firms do not have a particularly high rate of new product or process development relative to other New Zealand sectors or to other countries.

10.5 Data on Patenting

New Zealand's rate of modern biotech patent applications over the five years to the end of 2002 was 3.7 per million of population, per year. This is below the average for the G7 (5.3) and for a reference group of small, developed OECD economies (5.5). Patent application rates range from a high of 15.2 for Denmark to a low of 0.5 for Italy. Overall New Zealand ranks eleventh out of 18 with a patenting rate above that found in France and Japan. However New Zealand's performance is disappointing compared to other small countries with strong primary industries that it might hope to emulate e.g. Denmark (15.2), Switzerland (10.9), Netherlands (5.5), Australia (4.1).

Comparison of the three-year periods 1997-99 and 2000-02 reveals an average increase in patenting rates of 51%. New Zealand has increased its performance relative to the OECD and Australia; although the rapid change in patent application rates may, in part reflect an increased propensity to patent in universities and Crown Research Institutes.

Regressing C12N patenting rates against population produces a surprisingly good fit with 75% of the variation in applications being explained by population size. Based on this analysis New Zealand is very close to the trend line; its C12N patent rate is close to the expected value, after adjusting for population size. There are few real outliers, although Denmark and Switzerland have a rather higher patenting rate than expected, while the rate for Italy and Ireland is lower than expected (see section 6).

10.6 Biotech Alliances and Other Factors

Most enterprises (84%) responding to the 2002 biotech survey had at least one alliance involving biotech activity, 62% reported at least one New Zealand alliance while 41% reported an overseas alliance. Overseas alliances were most common in the tertiary education, and scientific research groups. The most commonly reported alliance purposes were product/process development; reported by 82% of respondents who had an alliance and basic research. Respondents were asked to rate ‘partnership outcomes to date’; 50% were described as ‘very productive’ and 44% as ‘somewhat productive’. Only 6% were reported to be ‘not very/not at all productive’. Further details of biotech alliances are reported in section 7.

Section 8 provides data on the main sources of information used by enterprises in the biotech sector while section 9 focuses on a range of other factors that affect innovative performance. There are some significant differences between industrial groups in the perceived importance of different factors. Enterprises in tertiary education place greater weight on ‘star scientists’ and ‘science push’ and regard ‘appropriability’ and ‘demand-pull’ as less important. By contrast, primary product enterprises rank ‘demand-pull’ and appropriability as being more important.

This paper has provided a detailed description of the New Zealand biotech sector based on data collection and analysis carried out by Marsh (2001a; 2002) and a review of secondary sources. This description sets the scene and provides context for a study of the determinants of innovation – see Marsh (2004). Prior to this analysis our knowledge of most sector parameters was very limited or completely lacking. There is a need for policy makers to make more use of the available data, rather than continuing to use less reliable estimates produced by organisations that have a vested interest in exaggerating the size of the sector.

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